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JOURNAL
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Volume XL NOVEMBER, 1958 Number 4

ESTIMATION OF SPATIAL PRICE EQUILIBRIUM MODELS

G. G. JUDGE AND T. D. WALLACE
Oklahoma State University

Introduction

ECONOMISTS have been concerned over a long period of time with the development of a general theory of location and space economy. General equilibrium theory as elaborated by Walras, Pareto and Wicksell and its modern counterpart as exemplified by the writings of Hicks, Mosak, Lange and Samuelson, treats an economy in which all factors and producers, products and consumers are, in effect, located at one point (transportation costs are taken as zero). Productive efforts by such men as Weber, Englander, Ohlin, Palander, Hoover, Losch and others have extended the general theory in the direction of embracing the total spatial array of economic activities. Contributions by Leontief[1] in developing the input-output technique for general equilibrium analysis, and by Koopmans,[2] Dantzig,[3] and others in developing the activity analysis model of production and allocation are of consequence here since they permit an attack on a specific set of significant problems which logically fall within the province of a general theory of location and space economy. With the objective of specifying a conceptual framework and the design of the corresponding operational model, Enke,[4] Samuelson,[5] Beckmann[6] and Baumol[7] set out the problem of interconnected competitive

[1] Leontief, W. W., *Studies in the Structure of the American Economy*, New York: Oxford University Press, 1953.

[2] Koopmans, T. C., "Optimum Utilization of the Transport System," *Econometrica*, Vol. 17, Supplement, July 1949, pp. 136-46.

[3] Dantzig, G. B., "Application of the Simplex Method to a Transportation Problem," Cowles Commission Monograph 13, New York: John Wiley and Sons, pp. 357-374.

[4] Enke, S., "Equilibrium Among Spatially Separated Markets: Solution by Electric Analogues," *Econometrica*, Vol. 19, 1951, pp. 40-48.

[5] Samuelson, P. A., *Foundation of Economic Analysis*, Cambridge: Harvard University Press, 1947.

[6] Beckmann, M., "A Continuous Model of Transportation," *Econometrica*, Vol. 20, 1952, pp. 643-60.

[7] Baumol, W. J., "Spatial Equilibruim with Supply Points Separated from Markets with Supplies Predetermined," Ditto Report, Bureau of Agricultural Economics, USDA, Washington, D.C., 1952.

markets in a new form, and at the same time open a new approach to spatial pricing systems and competitive locational equilibrium. This new operational formulation permits space to be treated explicitly and presents the rationale whereby a purely descriptive problem in nonnormative economics can be converted into an extremum problem in which linear programming can be employed as a tool of analysis. By converting the spatial equilibrium system into an extremum problem, insights can be obtained relative to the geographic location of production, spatial equilibrium prices and the optimum geographical flows consistent with a given set of data.

In addition to being operational in the sense that computations involved are manageable, solutions to spatial equilibrium models of the Enke-Samuelson type generate information that is basic to choice by decision makers at the government and firm levels. For example, using the method of comparative statics, the spatial equilibrium models can be used to ascertain the consequences of changes in: (1) transport costs, (2) the level and regional distribution of production, (3) the level and distribution of consumer income, and (4), the level and regional distribution of population, on geographical prices, production, consumption and flows. Given the setting, this paper contains an operational model of the spatial framework defined by the Enke-Samuelson formulation of spatial price equilibrium analysis and applies it to the beef sector of the economy.

The General Problem

The general problem of equilibrium among spatially separated markets has been stated in one of its simplest forms by Enke. His formulation proceeds as follows: "There are three (or more) regions trading a homogeneous good. Each region constitutes a single and distinct market. The regions of each possible pair of regions are separated—but not isolated—by a transportation cost per physical unit which is independent of volume. There are no legal restrictions to limit the actions of the profit-seeking traders in each region. For each region, the functions which relate local production and local use to local price are known, and, consequently, the magnitude of the difference which will be exported or imported at each local price is also known. Given these trade functions and transportation costs, we wish to ascertain: (1) the net price in each region; (2) the quantity of exports or imports for each region; (3) which regions import, export, or do neither; (4) the aggregate trade in each commodity; (5) the volume and direction of trade between each possible pair of regions. . . ."[8] Enke then suggests how a solution to this problem may be obtained by electric analogue.

Samuelson has demonstrated how the Enke problem contains within

[8] Enke, *op. cit.*, p. 41.

it the following Koopmans-Hitchcock minimum transportation cost problem: "A specified number of (empty or ballast) ships is to be sent out from each of a number of ports. They are to be allocated among a number of other receiving ports, with the total sent in to each such port being specified. If we are given the unit costs of shipments between every two ports, how can we minimize the total cost of the program?" It should be noted that the Koopmans-Hitchcock problem implicitly assumes that the scale of output and the demand in each given region are known.

Samuelson has investigated the many-region location problem posed by Enke, and has suggested how it can be couched mathematically into a maximum problem which can be solved by trial and error or by a systematic procedure of varying shipments in the direction of increasing the social pay-off. Baumol has presented a solution similar to that of Samuelson. Beckmann has extended the formulation and has considered the case of continuous geographical intensity distributions of production where every infinitesimally small area in an economy both produces and consumes a given commodity. Under these formulations, theoretically, both the geographic distribution of production and consumption and the optimum geographical pattern of interregional flows would have been derived simultaneously. Although these formulations ignore a number of basic locational forces, if a finite number of production and consumption points or regions are specified, the Enke-Samuelson-Beckmann models offer an efficient approach to spatial pricing systems and the determination of the resulting geographical flows of commodities.

From an empirical standpoint, the following studies should be mentioned. Fox[9] and Judge,[10] employing the Enke-Samuelson-Beckmann formulations, developed spatial price equilibrium models of the feed-livestock and egg sectors of the economy. Snodgrass and French[11] and Henry and Bishop[12] employed the transportation model as formulated by Koopmans to derive optimum geographical flows for the dairy and broiler meat sectors of the economy. These studies give an operational content to the theoretical formulations discussed and suggest the practicability of research relating to spatial pricing systems and competitive locational equilibrium.

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[9] Fox, K. A., "A Spatial Equilibrium Model of the Livestock-Feed Economy," *Econometrica*, Vol. 21, pp. 547-66, 1953; and Fox, K. A. and Taeuber, R. C., "Spatial Equilibrium Models of the Livestock-Feed Economy," *American Economic Review*, Vol. 45, pp. 584-608, 1955.

[10] Judge, G. G., "A Spatial Equilibrium Model for Eggs," Connecticut Agricultural Experiment Station Bulletin 318, Storrs, Connecticut, 1956.

[11] Snodgrass, M. M., and French, C. E., "Linear Programming Approach to Interregional Competition in the Dairy Industry," Indiana Agr. Expt. Sta. Bul. (in press).

[12] Henry, W. R. and Bishop, C. E., "North Carolina Broilers in Interregional Competition," Agricultural Economic Information Series, No. 56, North Carolina State College, 1957.

The Model

Assumptions

In an attempt to reduce the model to a simplified version of reality, the following restrictive and expository assumptions are made. Perfect competition assumptions dictate the requirements for the regional pattern of prices and flows of the commodity. Therefore, each firm is assumed to have the objective of maximizing profits and thus will make shipment decisions which yield the greatest per unit net return. The supply source and market for each geographical area is assumed to be represented by a fixed point. It is assumed that regional demands can be represented by known linear demand functions, and regional supplies are taken as predetermined for the given time period. All regions are connected by transport costs that are independent of the direction and volume of trade, and flows of beef among regions are assumed unhampered by governmental or other interference. It is further assumed that consumers are indifferent as to source of supply and that the product is homogeneous. The observed values of factors affecting regional consumption over and above the price of the commodity are taken as predetermined or given. Foreign imports and exports of beef are taken as negligible and it is assumed for any time period, t, that total production and total consumption of beef are equal.

Obviously, both production and consumption of beef can take place in all regions and beef consumed out of local production does not require transporting since each region is represented by a point. Another obvious assumption, although required explicitly in a mathematical sense, is that there can be no negative shipments. It may also be observed that as a result of the profit maximization postulate there can be no cross-hauling of the product; deficit regions cannot export and surplus regions can only export to deficit regions.

The Formal Model

Given the postulates and the objectives, the problem can be divided for simplicity into the following three parts: (1) determining optimum regional price differentials, (2) determining equilibrium beef prices, consumption and surpluses or deficits for all regions, and (3) deriving minimum cost flows of beef among regions. The determination of all unknowns is, of course, a mutually dependent process.

(1) *Determination of regional prices, consumption, excess demands and supplies:* The two-regional competitive case is presented since it can be easily diagrammed and provides an insight for the logic underlying the solution for the general case. Generalization to n regions is not straightforward but should prove simpler once the theoretical solution is estab-

lished for the trivial example. First consider the following geometrical representation.[13]

S_1 and S_2 represent fixed supplies for regions 1 and 2, respectively, and D_1 and D_2 depict linear demand schedules for the two regions. Assuming no interregional product movement, equilibrium price would be at P_1' and consumption would be established at A for region 1 while price and the quantity consumed in region 2 would be P_2' and B.

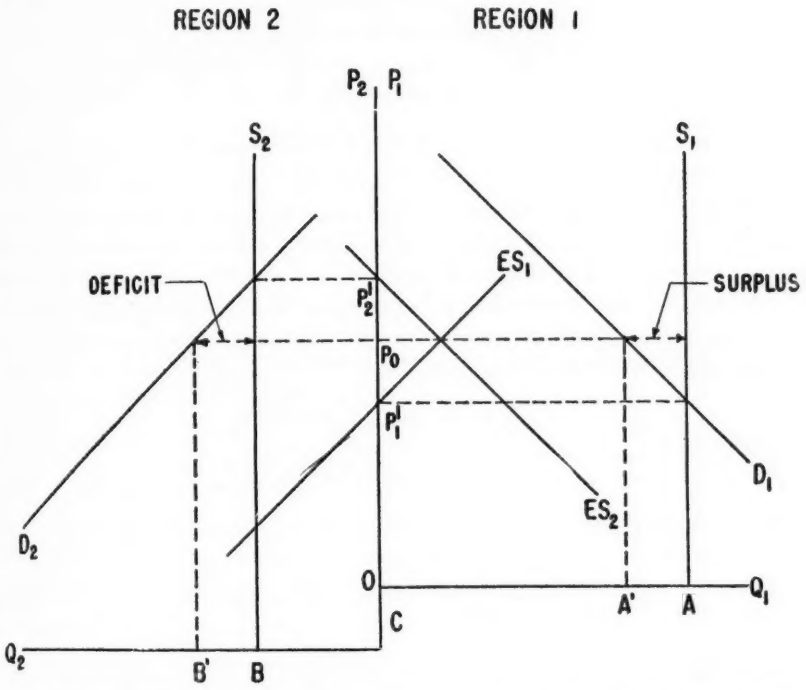

FIG. 2.1. DETERMINATION OF EQUILIBRIUM PRICES, CONSUMPTION AND SURPLUS AND DEFICIT QUANTITIES FOR THE TWO-REGION CASE

Now assuming that shipment between regions can occur at a unit transport cost of C, a joint equilibrium would be established at price P_0 for region 1 (determined by the intersection of ES_1 and ES_2, the excess supply curves for the two regions). The price for region 2 would be $P_0 + C$, and region 1 would consume the amount A′ while region 2 would increase consumption to B′. Obviously $A' + B' = A + B$ and thus $A - A' = B' - B$. Thus, knowing the demand schedules for regions 1 and 2, the supplies for both regions and the transport cost between the two regions

[13] See Judge, *op. cit.*, p. 9 and Samuelson, *op. cit.*, p. 286.

permits the determination of joint equilibrium prices and consumption for both regions, surplus and deficit production and the amount of the product that will be transported to satisfy the equilibrium conditions. Total transport costs may then be estimated by multiplying C times either $B' - B$ or $A - A'$.

The algebraic analogue of the geometric model (Figure 1) may be depicted as follows: let the two demand schedules be represented as:

$$D_1: \quad A' = \beta P_0 + k, \tag{2.1}$$

$$D_2: \quad B' = \beta(P_0 + C) + k, \tag{2.2}$$

and

$$A' + B' = A + B, \tag{2.3}$$

where β is the known slope and k the known intercept of the linear demand function (assuming that both regions have the same function).[14] $A + B$ is the total production or total consumption for both regions and is known. C represents the cost of transporting a unit of product between the two regions and is assumed fixed and known. The unknowns include A', B' and P_0, and equation (2.3) provides enough information so that equations (2.1) and (2.2) may be solved uniquely for these unknowns. Adding equations (2.1) and (2.2) yields:

$$A' + B' = 2\beta P_0 + \beta C + 2k, \tag{2.4}$$

and from (2.3):

$$A + B = 2\beta P_0 + \beta C + 2k. \tag{2.5}$$

The solution for P_0, the equilibrium price in the surplus region, yields:

$$P_0 = \frac{1}{2\beta}(A + B - \beta C - 2k). \tag{2.6}$$

Given the unique P_0, equilibrium price in the deficit region is, then, $P_0 + C$, and these values may be substituted into (2.1) and (2.2) for unique solution for A' and B'.

Before proceeding to the case of N regions, it should be pointed out that if the price differential $(P_1' - P_2')$, assuming no shipments, is less than the cost of shipping between regions, there would be no movement of the product between the two regions. Also, if the unlikely case of the price differential being equal to the unit transport cost occurred, either region would be indifferent to shipping a unit of product.[15]

In generalizing the two-region case to N regions, consideration is given to other regional factors that may be associated with the determination

[14] This assumption is, of course, not necessary for a unique solution of the problem.

[15] See Samuelson, *op. cit.* for a rigorous treatment of the various alternatives in question.

of the level of regional consumption. A typical equation for one region in the N region case may then be written as

$$Y_{1i} = \beta_i(Y_{20} + d_i) + \sum_{j=1}^{k} \alpha_{ij}Z_{ij} + \alpha_{io}, \qquad i = 1, \cdots, N^{16} \qquad (2.7)$$

where Y_{1i} is consumption in the i^{th} region, β_i is the known coefficient connecting consumption and price of the i^{th} region, Y_{20} is price in the base region, d_i is the price differential between region i and the base and may be zero, positive, or negative, Z_{ij}, $j = 1, \ldots, k$, represents all other factors that may affect regional consumption such as population, income, prices of complementary and competing products, etc., the α_{ij} are the coefficients of the Z_{ij} and α_{io} is the equation constant. It is assumed that the β_i, d_i, α_{ij}, Z_{ij} and α_{io} are known. Summing equation (2.7 over the N regions yields:

$$\sum_{i=1}^{N} Y_{1i} = Y_{20} \sum_{i=1}^{N} \beta_i + \sum_{i=1}^{N} \beta_i d_i + \sum_{i=1}^{N} \sum_{j=1}^{k} \alpha_{ij}Z_{ij} + \sum_{i=1}^{N} \alpha_{io} \qquad (2.8)$$

Since total consumption $\left(\sum_{i=1}^{N} Y_{1i}\right)$ for the N regions is assumed equal to total production which is known, equation (2.8) can be solved for Y_{20} (the price in the base region).

$$Y_{20} = \frac{1}{\sum_{i=1}^{N} \beta_i} \left[\sum_{i=1}^{N} Y_{1i} - \sum_{i=1}^{N} \beta_i d_i - \sum_{i=1}^{N} \sum_{j=1}^{k} \alpha_{ij}Z_{ij} - \sum_{i=1}^{N} \alpha_{io} \right] \qquad (2.9)$$

With Y_{20} determined and assuming the d_i, $i = 1, \ldots, N$, are known, equilibrium regional consumption can be established for all regions by substituting $Y_{20} \pm d_i$ in the regional demand equation (2.7). Unfortunately, the d_i are not ordinarily known for the N case since in considering more than two regions, the price advantage is no longer strictly equal to the transport cost between the base and the i^{th} regions. The problem relating to the determination of the d_i will be discussed in the next section.

Assuming for the moment that the d_i, $i = 1, \ldots, N$ are known, for all regions, the amount of surplus or deficit product for each region can be calculated, since production or available supply is assumed predetermined for each region.

(2) *Minimum cost flows of beef among regions:* Given the surplus and deficit regions and the quantities of the commodity involved in each case, the problem of determining minimum cost flows may be treated as a linear programming problem. To make the problem explicit, the following tableau is employed.

[16] Here the assumption that the demand function is homogeneous for all regions is omitted.

TABLE 2.1. THE GENERAL TRANSPORTATION PROBLEM TABLEAU

Origins (Surplus Regions)	Destinations (Deficit Regions)										Totals
	i|j	(1)	(2)	·	·	·	·	·	·	(m)	a_i
	(1)	C_{11}	C_{12}							C_{1m}	a_1
	(2)	C_{21}	C_{22}							C_{2m}	a_2
	·										·
	·					X_{ij}					·
	·										·
	·										·
	·										·
	(n)	C_{n1}	C_{n2}							C_{nm}	a_n
Totals	b_j	b_1	b_2	·	·	·	·	·	·	b_m	$\sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j$

With the determination of the a_i and b_j (excess supplies and demands), $i = 1, \ldots, n$; $j = 1, \ldots, m$; $n + m = N$, the problem is one of satisfying all demands out of total supplies in such a way as to minimize transport costs. The problem may be stated algebraically as finding a set of X_{ij} such that:

$$\sum_{j=1}^{m} \sum_{i=1}^{n} X_{ij} C_{ij} = \text{minimum} \tag{2.10}$$

subject to:

$$\sum_{j=1}^{m} X_{ij} = a_i; \qquad i = 1, \cdots, n. \tag{2.11}$$

$$\sum_{i=1}^{n} X_{ij} = b_j; \qquad j = 1, \cdots, m. \tag{2.12}$$

$$\sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j, \tag{2.13}$$

and

$$X_{ij} \geq 0 \qquad \text{for all } i, j. \tag{2.14}$$

where X_{ij} represents the amount of product shipped from the i^{th} surplus region to the j^{th} deficit region; a_i represents the amount of product available for export from the i^{th} surplus region; b_j is the amount required by the j^{th} deficit region and C_{ij} is the per unit cost of shipping from the i^{th} surplus to the j^{th} deficit region. There are many solutions to (2.11) and

(2.12) subject to (2.13) and (2.14), and given any feasible solution of $n + m - 1$ or $N - 1$ shipments, an iterative procedure known as the simplex method provides a means of converging to the optimum program (the one that satisfies (2.10)).[17]

Therefore, given the a_i's and b_j's (regional excess demands and supplies), the linear programming transportation model may be used to determine the optimum distribution system. After setting forth and carrying through the problem in this form, it can be shown that the resulting minimum cost set of flows is the one that would be determined under the conditions of perfect competition. The conclusion follows since the equilibrium prices are tied together by a specific set of transport costs and the relevant transport costs used in obtaining the optimum set of flows are less than for every possible alternative delivery which is not made. The solution obtained will be unique except for the case when two or more sources find two markets equally profitable. In this case, of course, more than one optimum shipment plan exists.

(3) *Determining regional price differentials (d_i):* If the regional price differentials are known, then one can proceed in a straightforward manner to derive the spatial equilibrium prices and flows. However, in the real world, these geographical price differentials constitute one of the unknowns necessary for a solution, since they condition regional prices and the level of regional consumption. Therefore, in some cases, the magnitude of the price differentials may determine whether a region is surplus or deficit and by how much.

Since for practical problems the number of regions employed are finite, it is possible to obtain an initial approximate set of price differentials by the following procedure. For any given time period, regional supplies and population are known and average total per capita consumption and per capita supply of each region are also known. This information can be used to initially partition each region as being surplus or deficit. Given information relative to the classification of each region, an approximate set of price differentials can be generated by employing the following rules: (1) if one region ships to another, the prices must differ by the known unit transportation cost and (2) if two surplus regions ship to the same deficit region, the difference between prices in the surplus regions will be equal to the difference between their unit transport costs to the deficit region. Thus, the system involves a structure of regional prices bound together by specific transport costs. By selecting the i^{th} region as the base, the approximate regional price differential may then be used to determine the equilibrium regional prices. These prices can be used to generate the data

[17] See Dantzig, *op. cit.*, pp. 359-73.

necessary for the transportation problem and thus the optimum geographical commodity flows under the assumed price differentials.

Up to this point, the analysis has proceeded on the basis that the initial vector of price differentials is the "correct" one. Also, the programming problem, as such, has been solved without recourse to price differentials, the prime economic allocators of regional distribution. However, as with any linear problem, the solution implicitly places values on the various inputs and outputs involved. Therefore, with the aid of the duality theorem of linear programming, a unique set of price differentials may be derived which correspond to the equilibrium set of flows and which may be used to check the approximate differentials of the initial formulation. Thus, given a minimum cost transportation solution, the dual problem is concerned with deriving the vector of regional price differentials consistent with this solution.

In developing the dual solution, let U_i and V_j be dummy variables with V_j associated with the destinations and U_i associated with origins or supply points. The problem may then be set forth in the following equations as that of maximizing:[18]

$$S = \sum_{j=1}^{M} b_j V_j - \sum_{i=1}^{N} a_i U_i \tag{2.15}$$

Subject to the restrictions:

$$V_j - U_i \leq C_{ij}, \tag{2.16}$$

$$V_j > 0. \tag{2.17}$$

Since equation (2.15) is equal to S, the total cost of transportation derived in the minimum formulation, the maximum problem may be thought of as finding the values of the U_i and V_j that will maximize the total gain in value of amounts shipped subject to nonpositive profits on each shipment. Within this framework, it is then possible to interpret the U_i as the value of the product at supply origin i and the V_j as the value of the product delivered at destination j. By rewriting equation (2.17) as

$$V_j \leq U_i + C_{ij}, \tag{2.18}$$

this relationship then states that for any supply-destination pair, the value at the destination must be no greater than the value of the input at the supply point plus transportation cost. For routes in the basis, destination value equals supply point value plus transportation costs. For these routes not in the basis, destination value is equal to or less than the supply point value plus transport costs. For any given problem, once the supply-destina-

[18] This development of the dual follows that given by R. Dorfman, P. A. Samuelson, and R. M. Solow, *Linear Programming and Economic Analysis*, New York: McGraw-Hill, 1958, pp. 122-127.

tion pairs are known, then for the set of pairs, equation (2.18) may be rewritten as

$$V_j - U_i = C_i'_j. \tag{2.19}$$

This then defines a set of linear equations involving $n + m$ unknown values of the U_i and V_j. Since there are only $n + m - 1$ observed unit transport costs in a basic solution, a unique solution to the set of equations requires assigning an arbitrary value to either one U_i or V_j. By then choosing the value at the i^{th} supply point as equal to zero, a set of price differentials is generated subject to this choice or base. Making use of the U_i and V_j estimates of the dual, objective estimates of the d_i, the regional price differentials, are obtained.[19]

In addition to providing objective estimates of the regional price differentials, the U_i and V_j also contain two types of useful economic information: (1) the values of U_i measure the comparative advantages of the surplus regions, and (2) the values of the V_j give the delivered price differentials that correspond to the most economical allocation of the supply from the viewpoint of minimum aggregate transportation costs.

The next step is to ascertain whether or not the set of price differentials generated by the dual solution agree with those developed in the initial approximate formulation. If the new set of price differentials differs from the initial formulation, the process of determining equilibrium prices and flows is repeated using the new estimates of the d_i. Thus, an iterative process is employed to determine the price differentials and the final stage is reached when the d_i, $i = 1, \ldots, N$ generated by the last optimum shipment program agree with the differentials used in determining equilibrium price, consumption, etc. The results of this iterative process are similar to those of basing-point prices in that the prices at each supply point are influenced by the transportation costs pertaining to the other supply points. Therefore, the prices at supply point 1 may be greater than those at supply point 2 because supply point 2 has a locational disadvantage and could not otherwise dispose of its product without loss. The results obtained in this manner are the competitive equilibrium solution that would result from the efforts of the supply points to dispose of their supplies at the maximum possible prices, and the solution to the value and flow problem is simultaneous and interdependent.

An Empirical Example

In order to demonstrate how the foregoing conceptual framework may be converted to an operational model, an example relating to the beef

[19] It should be mentioned that only the regional price *differences* are determinate by this formulation. The regional equilibrium prices or P_o plus or minus the price differential relative to the base region is determined by using equation (2.9).

marketing sector for the year 1955 is employed. First, the basic data underlying the specified problems is presented and then the spatial price equilibrium solution for one case is derived.

The Basic Data

As a first step in the analysis, the United States was divided into 21 contiguous regions.[20] The demarcation was restricted to one or more states for each region since the basic data are not available for smaller areas. A centrally located city was chosen as a market and supply point for each region. The regional demarcation and basing point cities are given in Table 3.1.

Because of the restrictions on the availability of state or regional consumption data, an aggregate market demand relationship for beef was specified to reflect demand in all regions.[21] This relationship was originally

TABLE 3.1. THE REGIONAL DEMARCATION AND VALUES OF THE PREDETERMINED VARIABLES

Region	States Included	Basing Cities	Total Beef Supply[1] (1,000 lbs.)	Per Capita Beef Supply (lbs.)	Per Capita Disposable Income ($)[2]	Population[3] (thousands)
1	Vt., N. H., Maine, Mass., Conn., R. I.	Boston	148,710	15.5	1,817	9,619
2	N. Y.	N. Y.	383,783	24.0	1,970	16,021
3	Md., Del., Wash., D. C., Pa., N. J.	Phil.	830,980	41.1	1,785	20,213
4	W. Va., Va., N. C.	Roanoke	198,091	20.0	1,180	9,907
5	Ky., Tenn.	Bowling Green	342,418	53.3	1,087	6,425
6	Mich., Ohio	Toledo	1,066,866	65.6	1,823	16,271
7	Ill., Ind.	Chicago	1,499,690	110.0	1,865	13,630
8	Minn., Wisc.	St. Paul	1,324,079	192.1	1,512	6,892
9	Nebr., Iowa	Omaha	2,109,061	518.8	1,362	4,065
10	Ka., Mo.	K. C.	1,167,530	186.5	1,523	6,261
11	Ala., Ga., S. C.	Atlanta	333,962	36.8	1,066	9,080
12	Fla.	Tampa	166,320	46.5	1,441	3,580
13	Ark., Miss., La.	Vicksburg	211,793	30.8	994	6,869
14	Okla., Tex.	Ft. Worth	947,597	86.5	1,386	10,958
15	N. Dak., S. Dak.	Bismarck	271,697	204.9	1,137	1,326
16	Wash., Ore.	Portland	387,357	90.3	1,677	4,292
17	Mont., Idaho	Butte	120,353	97.0	1,442	1,241
18	Wyo., Colo.	Denver	477,962	257.1	1,534	1,859
19	Utah, Nev.	Ely	108,058	104.7	1,528	1,032
20	Ariz., N. M.	Gallup	81,210	45.1	1,317	1,800
21	Calif.	Fresno	1,318,935	101.8	1,978	12,961
	United States		13,496,632	82.1	1,608	164,302

[1] Agricultural Marketing Service, "The Livestock and Meat Situation," U. S. Department of Agriculture, August 1948 and March 1956; Agricultural Marketing Service, "Livestock Slaughter," U. S. Department of Agriculture, May 1956, p. 4; and Agricultural Marketing Service, "Meat Animal, Farm Production, Disposition and Income, by States," U. S. Department of Agriculture, Bul. 184, 1956, pp. 6–10. For 1955, commercial slaughter in liveweight was added to farm slaughter and the total divided by the appropriate ratio to obtain carcass weight production by states.

[2] U. S. Bureau of Foreign and Domestic Commerces, "Supplement to Survey of Current Business," U. S. Department of Commerce, 1956, p. 141. Per capita disposable income is not available for 1955 on a state basis, so it was necessary to adjust these data on the basis of state personal income payment to obtain estimates of this series.

[3] U. S. Bureau of Foreign and Domestic Commerces, "Supplement to Survey of Current Business," U. S. Department of Commerce, 1956, p. 145. These data apply to population estimates as of July 1.

[20] The reader is probably aware that how to demarcate any territory into meaningful regions is a big problem in itself. As noted by a reviewer of this article, rules of regional demarcation need to be formalized since different systems of regions may yield different equilibrium solutions for any particular problem.

[21] Wallace, T. D., and G. G. Judge, "Econometric Analyses of the Beef and Pork Sectors of the Economy," Oklahoma Agricultural Experiment Station Bulletin, T-75, Stillwater, Oklahoma, Aug. 1958.

derived as a logarithmic function with price and income elasticity parameter estimates of demand for beef of -0.86 and 0.59, respectively. The logarithmic form was transformed to this linear relationship:

$$Y_{1i} = -1.0529Y_{2i} + .0303Z_{1i} + 104.9777 \qquad (3.1)$$

where Y_{1i} is per capita consumption of beef in the i^{th} region; Y_{2i} is equilibrium price in the i^{th} region and Z_{1i} is per capita disposable income in the i^{th} region. Since data relating to regional retail pork prices in 1955 are not available, the average impact of the price of this substitute commodity is included in the constant term.

The model further specifies the need for regional data pertaining to beef supplies, population and disposable income. These regional data were obtained from records published by the Department of Agriculture and Commerce. The data are assumed to reflect accurately the variables involved and are presented in Table 3.1.

The market and supply sources as formulated in the model are assumed to be designated by a single point in each region. Since the structure of transport rates for beef is basic to the spatial solution, it is necessary to obtain estimates of the costs between the points that represent each pair of regions.

A model to reflect transport rates between market and supply source points was postulated as

$$C_{ij} = \beta_1 M_{ij} + \beta_2 M_{ij}^{1/2} + \epsilon \qquad (3.2)$$

where C_{ij} represents the cost in cents of shipping a pound of beef carcass from point i to point j; M_{ij} is the mileage between i and j; β_1 and β_2 are unknown parameters to be estimated and ϵ is an unobservable random error. This functional form was postulated in the belief that transport rates are an increasing function of mileage but should increase at a decreasing rate. For obvious reasons, the function was postulated as having a zero intercept. Since beef is shipped by both truck and rail, equation (3.2) was specified for each of these types of transportation.

A sample of data was secured to represent all observable variables and the least squares procedure using moments about zero was used to estimate the unknown parameters. The results were:

$$C_{ij} = .0008M_{ij} + .0464M_{ij}^{1/2} \qquad \text{(Rail)} \qquad (3.3)$$

$$R^2 = .970$$

and

$$C_{ij} = .0015M_{ij} + .0226M_{ij}^{1/2} \qquad \text{(Truck)} \qquad (3.4)$$

$$R^2 = .969$$

The above functions were then used to estimate both rail and truck

rates between all pairs of regions. The minimum of these rates in each case was chosen as the relevant transport cost.[22]

Equilibrium Geographical Prices and Flows for Beef, 1955

The sequential procedure outlined in the model section was used to establish optimum price differentials between regions. In the interests of brevity, only the final stage of the procedure will be presented.[23] The stages omitted here include: determining an approximating set of regional price differentials; using these approximate differentials to determine Y_{20}, price in the base region; employing equation (3.1) to determine regional consumption; differencing production and consumption to determine which regions were surplus and which were deficit and the magnitudes of surpluses and deficits; employing the linear programming technique to arrive at the optimum (minimum cost) shipment pattern for beef; and finally, using the U_i and V_j provided by the dual solution in the final simplex tableau to establish a new set of regional price differentials.

Armed with a new set of "price" differentials (see Table 3.2), the procedure is now one of re-establishing price in the base and other regions, equilibrium regional consumption, etc. Region 9 (Iowa and Nebraska) was chosen as a base due to its proximity to the geographical center of the United States and to its being obviously surplus for the time period considered.

Following the procedure outlined in the model section for establishing price in the base region, the following equation is of consequence.

$$Y_{1i} = -1.0529(Y_{20} + d_i) + .0303Z_{1i} + 104.9777. \tag{3.5}$$

The above demand equation (3.5) is the same as presented previously (3.1) except that price in the i^{th} region is given by:

$$Y_{2i} = Y_{20} + d_i, \tag{3.6}$$

where Y_{20} is price in the base region and d_i is the price differential connecting the i^{th} region with the base region.

Multiplying both sides of the relationship (3.5) by P_i, population in the i^{th} region, and summing over all regions yields:

$$\sum_{i=1}^{21} P_i Y_{1i} = -1.0529 Y_{20} \sum_{i=1}^{21} P_i - 1.0529 \sum_{i=1}^{21} P_i d_i + .0303 \sum_{i=1}^{21} Z_{1i} P_i + 104.9777 \sum_{i=1}^{21} P_i \tag{3.7}$$

[22] The transport rates generated by using equations (3.3) and (3.4) do not include costs of loading and unloading and neglect the general overhead of transportation systems. It should be realized, however, that given a particular set of flows, these cost components become constants and do not have a bearing on the minimum solution.

Since $\sum_{i=1}^{21} P_i Y_{1i}$ is total consumption of beef in the United States and is assumed equal to the known total production of beef, $\sum_{i=1}^{21} P_i$ is total population, and $\sum_{i=1}^{21} Z_{1i} P_i$ is the total disposable income for the United States for 1955 and the P_i and d_i are known, the solution for Y_{20} is straightforward. Carrying through, Y_{20} was found to be 66.67 cents per pound. Price in the i^{th} region for all i, $i = 1, \ldots, 21$, was determined by using equation (3.6), and these estimates may be found in Table 3.2.

After determining regional prices, regional per capita consumption was estimated by using equation (3.1) or (3.5) and regional disposable income data (Table 3.1). The resulting estimates were multiplied by regional population estimates (Table 3.1) to obtain total regional consumption. Regional consumption estimates were then subtracted from the respective regional supply estimates (Table 3.1) in order to determine regional surpluses and deficits. Estimates of regional consumption, surpluses and deficits obtained in the manner described are presented in the following table. (Table 3.2)

TABLE 3.2. REGIONAL EQUILIBRIUM PRICES, CONSUMPTION AND SURPLUS AND DEFICITS FOR BEEF (1955), FINAL SOLUTION

Region	Price Differentials	Price	Per Capita Consumption	Total Consumption	Surplus and Deficit
		(cents/lb.)	(1,000 lbs.)	(1,000 lbs.)	(1,000 lbs.)
1	2.93	69.60	86.7	834,188	−685,478
2	2.76	69.43	91.5	1,466,503	−1,082,720
3	2.62	69.29	86.1	1,739,937	−908,957
4	2.39	69.06	68.0	673,644	−475,553
5	1.54	68.21	66.1	424,531	− 82,113
6	1.64	68.31	88.3	1,436,127	−369,261
7	.94	67.61	90.3	1,230,411	269,279
8	.08	66.75	80.5	554,705	769,374
9	0	66.67	76.0	309,046	1,800,015
10	.20	66.87	80.7	505,213	662,317
11	2.12	68.79	64.8	588,638	−254,676
12	2.84	69.51	75.4	270,035	−103,715
13	1.54	68.21	63.3	434,518	−222,725
14	.47	67.14	76.3	835,637	111,960
15	− .51	66.16	69.8	92,486	179,211
16	−2.21	64.46	87.9	377,243	10,294
17	−1.37	65.30	79.9	99,146	21,207
18	− .76	65.91	82.0	152,506	325,456
19	−1.56	65.11	82.7	85,343	22,715
20	.04	66.71	74.6	134,318	−53,108
21	−1.85	64.82	96.6	1,252,456	66,479

[23] See G. G. Judge and T. D. Wallace, "A Spatial-Price Equilibrium Analysis of the Beef Marketing System," Oklahoma Agricultural Experiment Station Bulletin, 1958 (at printers), for a presentation of the entire sequential process.

With the surplus and deficit values and transport costs between all surplus and deficit regions (obtained from equations (3.3) and (3.4)), the final step is to determine geographic flows of beef such that all supplies are exhausted, all demands are fulfilled and total transportation costs are minimized. To accomplish this, the linear programming model of transportation was again employed.[24] The optimum tableau is presented in Table 3.3.

The cells of Table 3.3 in which the bold face type appear represent the activities which appear in the final basic solution, and the corresponding number represents the quantities of beef involved in the optimum flow solution. For example, the optimum flow solution indicates that Region 9 (Iowa and Nebraska) would supply Region 2 (New York) with 741,033 pounds of beef; Region 21 (California) would supply Region 20 (Arizona and New Mexico) with 30,393 pounds of beef, etc. The plan type numbers appearing in the cells of Table 3.3 may be interpreted as the difference between direct and indirect transportation costs. The indirect costs refer to the opportunity cost of not including a particular activity (supply and destination combination) in the basic solution, or, alternatively, the consequences of including it in the basic solution. The general theory of the simplex solution states that an optimum is reached when all direct minus indirect costs are positive or zero. This solution indicates that a change of activity appearing in the basis would result in equal or added total costs. For example, Region 7 could ship a pound of beef to Region 1 only at a 0.22 cent loss, or by increasing total transport costs by 0.22 cents per unit shipped. Alternatively, it could be inferred that the transport cost between Regions 1 and 7 would have to decrease by at least 0.22 cents per pound before any beef would be shipped between the two, given the alternative shipping possibilities and costs.

The U_i and V_j appearing at the extreme boundaries of Table 3.3 are obtained by employing the linear programming dual and represent the price differentials between the base region (Region 9) and all other regions. They are determined by solving the set of linear equations

$$V_j - U_i = C_i'_j; \tag{3.8}$$

where $C_i'_j$ is the transport cost of shipping from region i to region j for those activities appearing in the optimal solution. Since there are $n + m$ (21) U_i and V_j and $n + m - 1$ (20) $C_i'_j$, one of the U_i or V_j must be assigned a value before the others are determinate. The U_i opposite Region 9 was chosen as zero in this case, and, therefore, the differentials are determined relative to this base. The choice of base could just as easily have been any of the other regions and the resulting differentials would have been in relation to that choice.

[24] Dantzig, G. B., *op. cit.*

TABLE 3.3. FINAL OPTIMUM FLOWS OF BEEF IN THE UNITED STATES (1955)
(1,000 lbs.)

Origins	Destinations										Totals	U_i
	1	2	3	4	5	6	11	12	13	20		
7	.22	.08	.08	.13	.46	269,279	.50	.67	1.19	3.86	269,279	0.94
8	327,705	341,687	0	.07	.38	99,982	.38	.45	.88	2.92	769,374	0.08
9	.05	741,033	908,957	150,025	.20	.03	.17	.17	.38	2.26	1,800,015	0.00
10	.19	.06	.66	325,528	82,113	.23	254,676	.11	.19	2.30	662,317	0.20
14	1.03	.89	.91	.68	.74	1.36	.33	.13	111,960	2.19	111,960	0.47
15	179,211	.02	.04	.24	.62	.20	.43	.38	.96	2.11	179,211	−0.51
16	10,294	.04	.07	.15	.61	.34	.31	.20	.63	.60	10,294	−2.21
17	21,207	.03	.10	.16	.58	.29	.35	.21	.84	.67	21,207	−1.37
18	147,061	.03	.05	.03	.22	.29	.12	67,629	110,766	.49	325,456	−0.76
19	.20	.23	.25	.35	.58	.47	.46	.10	.60	22,715	22,715	−1.56
21	.58	.62	.65	.52	1.03	.91	.32	36,086	.16	30,393	66,479	−1.85
Totals	685,478	1,082,720	908,957	475,553	82,113	369,261	254,676	103,715	222,725	53,108	4,238,307[1]	
V_j	2.93	2.76	2.62	2.39	1.54	1.64	2.12	2.84	1.54	.04		

[1] Totals may not be additive due to rounding. Total transport cost = $104,756,372.

Since the price differentials (U_i and V_j) yielded by the optimum tableau agree with the differentials used to obtain equilibrium prices, consumption, and surpluses and deficits, the sequential process is complete. It is possible that one would have to repeat the process if the two sets of price differentials were not in agreement.

The resulting U_i and V_j of the final optimum solution contain two types of useful economic information. First, the U_i measures the comparative location advantage of the supply points relative to Region 9 (Iowa and Nebraska). For example, beef is worth 0.94 cents per pound more at Region 7 (Indiana and Illinois) than at Region 9 because of its proximity to the consuming centers of the East. Alternatively, beef is worth 0.76 cents per pound less in Region 18 (Wyoming and Colorado) than at Region 9 because of its distance from the major consuming centers. Second, the values of the V_j give the delivered price differentials relative to Region 9 for the deficit regions. For example, the price of beef is 2.93 cents per pound higher in Region 1 (New England) than in Region 9. The resulting price differentials obtained are the competitive equilibrium price differentials (or prices) that would result from the 11 surplus regions attempting to sell their excess supplies to the 10 deficit regions at the maximum possible gain. Therefore, the optimum values and the direction of flows are simultaneously and interdependently determined.

General Implications

The specification and solution of spatial models and their dual system may be used to obtain insights to many theoretical problems involving economic choice. By employing this new type of analysis, the efficiency and competitive structure of individual sectors may be investigated and knowledge may be obtained relative to problems of industrial structure and comparative-statics when the consequences of changes or actions are desired.

From a methodological point of view, analyses of this type yield implications for many areas of economic research. The requirements of specifying spatial market demand relationships generate a need and use for parameter estimates such as price and income elasticity which are the prime objectives of sector models. Furthermore, by using these parameter estimates, it is possible to obtain estimates of spatial consumption patterns under alternative price, income and population situations. By using these market demand relationships and employing the linear programming dual, it is possible to obtain regional price differentials that are consistent with a perfectly competitive market formulation. This type of spatial model is valuable because it is operational research-wise and the computations required are manageable. By employing principles

which seek to narrow down the number of geographical market and supply points, the spatial formulation alluded to in the preceding sections treats the space factor explicitly and offers an efficient approach to the determination of regional prices and the resulting geographical flows of a commodity. The model has general application and can be applied to any industry or sector which satisfies the underlying assumptions with a reasonable degree of accuracy.

From an economic policy point of view, the interdependent nature of our economy necessitates an analytical model, depicting the joint determination of sector variables, if the consequences and repercussions of certain policy actions are to be isolated. In this connection, spatial models offer an operational tool to the policy maker since they can be used to answer questions of a comparative static nature and thus indicate the changes in the optimum values of geographical prices, flows and differentials brought about by a specified change in the data or action. In particular, the model provides information basic to determining the consequences under given conditions of changes in (1) transport costs, and (2) geographical distribution of population, income and product supply, on the level of geographical prices and flows.[25] The comparative static method of analysis may be best illustrated by an example. How would the optimum solutions for 1955 change if the transport costs between each pair of points were increased by 20 per cent? To answer this question, the existing cost structure could be changed by 20 per cent, and the new optimum solutions recomputed and compared with the initial result. The number of admissable alternative applications of this type are, of course, very large and depend on the "if-then" questions to be asked. Knowledge generated by application of the model permits a ready application to such practical problems as production-shifting legislative policies or the level and structure of transport rates. By employing this type of analysis, policy makers may estimate in advance of a specified change both the direction and magnitude of the disturbance on the system.

As a basis for policy action, the perfect market concept used in formulating the spatial equilibrium models provides a standard of comparision whereby the pricing and distribution of a commodity can be judged as efficient or inefficient relative to this base. The impact or value of this normative approach to economic policy rests, of course, on the relationship of the conceptual model to general welfare. The normative model, in this case the competitive model, depicts what could happen under given ends and assumptions and this may not indicate what will obtain in the real world. However, from an economic policy standpoint, when "what

[25] For empirical examples of how spatial equilibrium analysis may be used to answer these and other related questions, see Judge and Wallace, *op. cit.*

could be" and "what is" differ, the divergence does indicate possible areas for choice or action. For example, what are the consequences of slaughtering beef in the region where produced rather than shipping it live to consumer-oriented processing plants? Whether or not action will be taken, will of course, depend on the goals to be pursued.

Spatial equilibrium analysis provides implications for both the producing and processing firms. For example, in regard to the beef producing firm, these analyses should suggest how changes in transportation costs, and the geographical distribution and level of population, income and supply might alter beef prices. These expected prices could then be used as a basis for resource adjustments. By introducing the time dimension, insights into the changing character of the beef industry may be discerned and the long-run competitive position of one region relative to another can be analyzed.

From the standpoint of the processing and distributing firm, the information provided by the analyses should make possible a rational choice among alternative geographical destinations of product shipments. By employing the duality theorem of linear programming, a unique set of regional price differentials can be derived which corresponds to the optimum set of product flows. These results may then be used by the processing firm in ascertaining the comparative or locational advantage of one region relative to others. Through this analysis, some insights into the optimum geographical location of processing firms may be obtained which are a function of both location and the scale of the firm.

The specified postulates underlying the general model presented make explicit the restrictive assumptions under which the analysis proceeds. Obviously, these assumptions may introduce uniformities which are at variance with the actual situation for particular problems; thus, there is a need in many instances to alter the model specification to correspond more accurately to the real world. The flexibility of the techniques now available permits the specification of models that reflect a wide variety of situations. Of course, the particular set of assumptions chosen by the investigator is conditioned by the situation to be reflected and the type of inferences deemed relevant. The purpose of this article was to present the logic underlying the estimation of a simplified spatial price equilibrium model and to suggest the economic implications of such an analysis for decision making. It is hoped that this presentation will encourage further research that will extend the analysis in the direction of spatial models that are more general and, perhaps, more consistent with particular real world problems.

'PRICE MAPPING' OF OPTIMUM CHANGES IN ENTERPRISES*

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IN A RECENT STUDY of dairy farms in North Carolina, optimum enterprise combinations were determined for several combinations of different prices of milk and labor. Linear programming techniques were used to determine the optimum enterprise combinations. After optimum combinations of enterprises were determined for the selected combinations of milk and labor prices, the next problem was to determine by how much the prices of milk and labor could vary without bringing about a change in the optimum combination of enterprises.[1]

The very narrow range of prices within which enterprise combinations are stable in a number of the situations created an interest in further analysis of these relatively unstable conditions. The purpose of this paper is to discuss selected problems encountered and the results of this additional analysis.

Resource Restrictions, Factor Supply, Product Demand, Technical Data, and Activities Considered[2]

The following assumptions were established after an empirical study of a sample of farms and with the aid of production specialists who have had experience with production possibilities in the area. In the selected farm situation, land available for pasture and crops consists of 110 acres. It is assumed that the farm is a "going business" and expects to continue in operation for a long period of years. To insure a minimum degree of crop rotation, consistent with maintaining soil productivity, not more than 76 acres should be used for crops, and not more than 34 acres for row crops in any one year. In one case there is no tobacco allotment, and in the second case there is a tobacco allotment of eight acres.

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[1] See, J. E. Faris and W. W. McPherson, "Application of Linear Programming in an Analysis of Economic Changes in Farming," *The Review of Economics and Statistics*, Vol. 39, No. 4, November 1957, pp. 421-434.

[2] A very limited set of situations are used here for illustration and to provide minimum background material essential for any understanding of the problems and results of the "price mapping." For additional background and results, see, J. E. Faris and W. W. McPherson, *Adjustments in Milk Supply, Grade A Dairy Farms, North Carolina Piedmont*, North Carolina Agricultural Experiment Station Technical Bulletin 136 (in process of publication).

The bi-monthly estimates of available family labor are as follows: December and January, 579 hours; February and March, 576 hours; April and May, 700 hours; June and July, 913 hours; August and September, 816 hours; and October and November, 772 hours. In the "price mapping" analysis additional labor is available in unlimited quantities at wage rates varying from 40 cents to $1.20 per hour.

It is assumed that there is no mortgage on the farm resources, that up to $20,000 could be borrowed at 4.5 per cent interest for real estate facilities, and that there are existing dairy facilities for 24 cows. Additional cows would require additional investment in real estate facilities. For all other factors it is assumed that supply to any given farmer is perfectly elastic at the specified prices.

For the individual farmer it is assumed that the demand for tobacco is perfectly elastic, at the specified price, up to the limit of the quantity produced on the allotted acreage. Beyond that quantity, this crop would be unprofitable as a result of the reduction in price (or penalty for exceeding quota which would add to the marginal cost). For all other products the demand is assumed to be perfectly elastic at specified prices. However, the price of milk is varied from $4.75 to $6.25 per hundredweight in the "price mapping" problem.

Enterprises, or activities, used in the analysis, unit level, "net return" and labor inputs are given in Table 1. "Net return" is the difference between annual revenue and annual *variable* expense; thus, there is a difference between net return when produced with existing facilities and when produced with additional facilities. A number of items of expense that are fixed when production is, with existing facilities, are variable when production is, with additional facilities. "Net return" is not a measure of

Table 1. Enterprises, Unit, Net Return, and Labor Inputs

Enterprise	Unit	Net return per unit (dollars)[a]	Hours of labor per unit						
			Dec.–Jan.	Feb.–March	April–May	June–July	Aug.–Sept.	Oct.–Nov.	Total
Corn	1 acre	82.05	.3	.9	3.3	2.8	0	3.8	11.1
Oats and lespedeza	1 acre	54.75	0	.6	.7	3.8	4.3	3.2	12.6
Baled alfalfa	1 acre	62.02	0	1.3	2.7	5.3	3.7	0	13.0
Tobacco	1 acre	440.43	0	16.3	28.8	107.3	190.5	137.4	480.3
Layers[b]	1000 hens	2,068.65	184	256	244	184	184	172	1,224
Hogs[b]	5 sows	599.36	58.0	72.3	82.0	62.0	77.7	69.0	421.0
Dairy:									
Present facilities									
All forage									
Purchased[c]	24 cows	5,553.41	320.6	362.6	281.3	305.0	353.5	305.3	1,928.3
Forage grown[d]	24 cows	7,114.29	322.9	387.5	335.8	384.3	472.1	309.1	2,211.7
Additional facilities									
All forage									
Purchased[c]	25 cows	5,234.90	334.0	377.7	293.0	317.7	368.2	318.0	2,008.6
Forage grown[d]	25 cows	6,860.80	336.4	403.6	349.8	400.3	491.8	322.0	2,303.9

[a] Net returns from activities using family labor. To obtain the net return from an activity using hired labor it is necessary to subtract the hours of labor per unit multiplied by the hourly wage rate.
[b] All feed purchased. In each livestock activity grain crops are entered at a market value; handled in this manner the grain is "sold" to the livestock on the farm or is sold direct from the farm if direct sale is more profitable.
[c] All forage except pasture is purchased.
[d] All forage produced on the farm.

family disposable income; but the maximizing of "net return" is consistent with the maximizing of family disposable income.[3] It is assumed that enterprises conducted with hired labor would use the same amount of inputs and would produce net returns equal to those produced with family labor minus the cost of labor. The technical coefficients are based on estimates of optimum production techniques and input levels. Consequently, the results show what it would "pay" farmers to do in specified situations, not necessarily what they are likely to do.

The price of milk and the wage rate are selected as the variables in the "price mapping" problem because these two items are deemed to be major factors determining optimum enterprise combinations. Estimates of future values of these two items are surrounded by a high degree of uncertainty, and any analysis that covers a range of values should increase considerably the usefulness of the results as guides to future adjustments in farm production. On the farms included in the study, milk is the principal product. The farms are in an area in which industrial activity has been increasing and labor costs in agriculture have been rising almost continuously for several years. More labor is employed per dollar value of output in tobacco production than in the production of alternative farm products. Under these circumstances, and with present production technology, it is thought that increasing wage rates are more likely to bring about reductions in tobacco production rather than a substitution of capital for labor to any great extent in tobacco production.

Optimum Enterprise Combinations and Optimum Changes in Response to Variations in Prices of Milk and Labor

Dairy Farm with No Tobacco Allotment

The program of activities was established initially with the wage rate at 60 cents per hour and milk at $5.64 per hundredweight. The results are given in line A of Table 2. The next task is to establish the price-wage limits within which the optimum combination of enterprises would not change. The results are given in section A of Figure 1. The analysis is continued in such a manner as to establish the optimum changes in enterprise combinations as wages and milk prices change throughout the ranges under consideration. The results are shown in Table 2 and Figure 1.[4] The major

[3] McPherson, W. W., "Some Fundamental Economic Concepts and Economic Analysis of Costs," *Journal of Farm Economics*, Vol. 33, No. 2, May 1951, pp. 192-203.

[4] The procedure used to develop the original or unmodified price maps, Figures 1 and 3, is described, for the case of varying two product prices, by Clifford Hildreth, see: Clifford Hildreth, "Some Problems and Possibilities of Farm Programming" in *Economic and Technical Analysis of Fertilizer Innovations and Resource Use*, E. L. Baum, *et al.* (ed.), The Iowa State College Press, Ames, (1957), pp. 253-256. Also, see Wilfred Candler, "A Modified Simplex Solution for Linear Programming."

Table 2. Enterprises Selected in Optimum Combinations, Varying Prices of Milk and Labor, Initial Programming Process, 110-Acre Dairy Farm, No Tobacco Allotment, North Carolina

Enterprise combination[b]	Enterprises[a]						
	Number cows				Thous. layers	Acres corn	Acres alfalfa
	Present facilities		Additional facilities				
	Forage produced	Forage purchased	Forage produced	Forage purchased			
A	24	0	8	0	4.5	23.5	0
B	0	24	0	18	4.1	33.4	0
C	0	24	0	18	4.1	32.9	0
D	24	0	0	0	4.8	26.1	18.9
E	24	0	0	0	4.9	26.1	19.4
F	19	0	0	0	4.8	27.8	31.1
G	0	24	0	36	3.4	0	0
H	0	24	0	37	3.4	0	0

[a] Division of activities between hired labor and family labor, and forage crops produced and consumed by the dairy enterprise are not shown.
[b] See Figure 1 for map of prices of milk and labor.

change as milk price increases is to increase the number of cows, increase feed purchased, and decrease feed produced on the farm. The fact that the approximately vertical boundaries of the various sections of the price map are slanting indicates that, at any given price of milk, a change in wage rate may change the optimum combinations of enterprises.

There is a difference between the results as shown in the price map (Figure 1) and what it would pay the farm to do if the farm, in fact, actually responded to each price change rather than each change originating from the program of the initial prices, because of the difference between net return with *present* facilities and net return with *additional* facilities in those enterprises in which long-term investments are incurred. For example, if the farm moved from a situation in which only existing facilities are used to one in which additional facilities are required, part of the variable expense of the change would become fixed expense after the change, and the boundaries of the price map section into which the firm moved would be shifted outward. That is to say, if the farm moved from enterprise system A to B, facilities for additional cows would be established. Then the boundary lines at which system B would be changed to C or back to A would shift to the right and left, respectively.

In the initial programming process eight enterprise combinations appeared. The next question for consideration is this: Are there optimum combinations of enterprises that could be eliminated without significantly

with Variable Prices," *Journal of Farm Economics*, Vol. 39, May 1957, pp. 409-428, and Faris and McPherson, "Application of Linear Programming . . . ," *The Review of Economics and Statistics*, Vol. 39, No. 4, pp. 421-434.

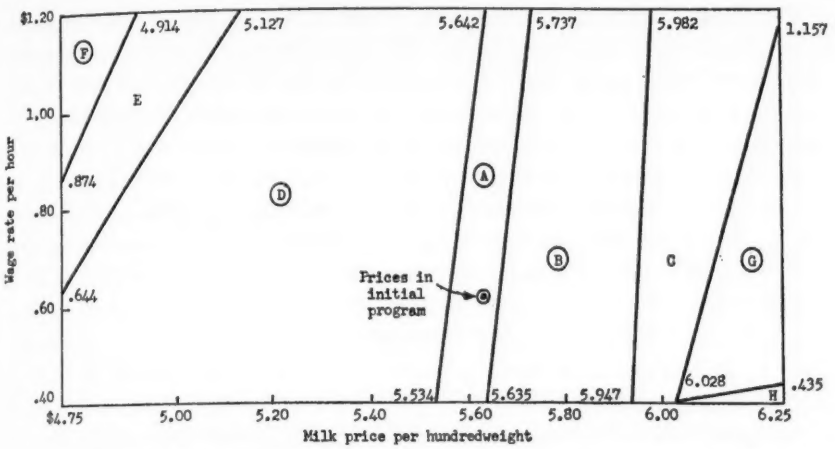


FIG. 1. "PRICE MAP" OF OPTIMUM ENTERPRISE COMBINATIONS WITH VARYING PRICE OF MILK AND WAGE RATE, 110-ACRE DAIRY FARM, NORTH CAROLINA (ORIGINAL)[a]

[a] The enterprise combinations selected to develop the adjusted price map shown in Figure 2 are circled. Activities in each enterprise combination are given in Table 2.

reducing the income opportunities of the farm? In order to answer this question the net return was computed at each corner of each section of the price map for each of the optimum enterprise combinations. From the results it was possible to determine the maximum extent to which net return would fall below optimum if milk price and wage rate fell in any one section of the price map when any one of the seven nonoptimum enterprise combinations was selected. (See Table 2 and Figure 1.) At the same time the set of activities in each enterprise combination was examined to detect differences in physical characteristics, such as number of cows, forage produced or purchased, number of hens, and acreages of the various crops.

At no point in section H of the price map would the net return of enterprise combination G fall below the net return of enterprise combination H by more than $50.[5] The same statement is true when incomes of H and G are compared at points in section G. A similar situation exists between B and C as well as between D and E. (See Table 2 and Figure 1.) Thus in any given situation any choice between G or H, B or C, and D or E would make very little difference in income or any other factor likely to influence decisions. Obviously, at least three enterprise combinations can be eliminated without materially affecting income opportunities.

[5] The difference, or relative loss in net revenue, that is accepted as a guide for eliminating enterprise combinations and sections of the price map is largely arbitrary or a matter of practical judgment. In this analysis no enterprise combination was eliminated unless the net return of at least one remaining enterprise combination was within $50 of the one eliminated.

The next problem is to determine which three enterprise combinations to eliminate from the three pairs now considered. For that decision two factors that are given major consideration are location and size of the section covered on the price map. Of the enterprise combinations included in the original map, as given in Figure 1, H, C and E are eliminated. Although H covers a very small area, the lower and right boundaries are established arbitrarily by not considering milk prices above $6.25 nor wage rates below 40 cents. The right boundary of section G is arbitrary also. Under these circumstances, enterprise combination G is retained in preference to H. The area of the price map covered by B is larger than area C; so, enterprise combination B was retained in preference to C. Enterprise combination D is retained in preference to E for a similar reason. If the choice were between E and F rather than E and D, F probably would be retained because it is quite likely that the outside boundaries arbitrarily limit area F to a greater extent than in the case of E.

After enterprise combinations E, C, and H are eliminated, the boundaries of the remaining sections of the price map are adjusted by determining at which points on the price map adjacent enterprise combinations would produce equal net returns. The results of the adjustment or modification are shown in Figure 2. The enterprise combinations are shown directly on the price map. However, in Figure 2 the acreages of pasture

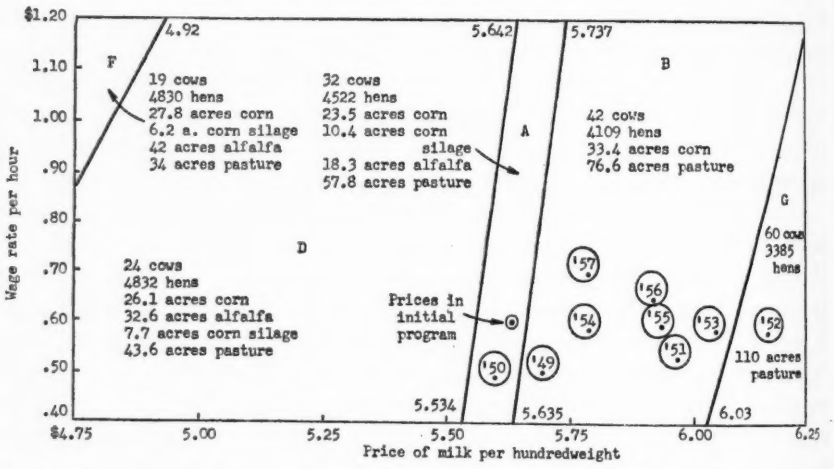


Fig. 2. "Price map" of optimum enterprise combinations, 110-acre dairy farm, varying wage rate and milk price, actual wage rates and milk prices in 1949 to 1957, North Carolina (adjusted)[a]

[a] Actual prices shown are annual average for North Carolina, Federal-State Crop Reporting Service, 1957 estimated by adjusting average of first four months for seasonal pattern. See Figure 1 for original price map from which this adjusted one was developed.

and harvested forage produced for the dairy herd as well as the market activities are shown.

Despite the fact that three enterprise combinations were eliminated in the development of the adjusted price map, the milk price ranges in section A (for enterprise combination A) are rather narrow. At any given wage rate, a change of 10 cents or less in milk price would change the optimum enterprise combination materially—an increase of 10 cows or a decrease of eight cows, and changes in the size of the poultry enterprise and in acres and content of the crops program. But the "costs" of making certain mistakes in enterprise selection, even among those remaining, would not be very great. Any farmer might very well choose to eliminate A, especially when faced with rather uncertain conditions with respect to milk prices. If enterprise combination B were selected and the milk price-wage combination lay in section A of the price map, the maximum extent to which net return could fall below optimum would be $92. (See line B2 of column A, Table 3.) Or, if enterprise combination D were selected and the milk price-wage combination fell at the most adverse point in section A of the price map, net return would be only $71 below the optimum. On the other hand, enterprise combination A would produce a net return of $469 below optimum at the most adverse point in section B and $613 below optimum in section D of the price map.

TABLE 3. MAXIMUM AND MINIMUM NET RETURN FROM OPTIMUM ENTERPRISE COMBINATIONS AND DIFFERENCES WHEN ENTERPRISE COMBINATIONS ARE NOT CHANGED IN RESPONSE TO CHANGES IN MILK PRICE AND WAGE RATE, 110-ACRE DAIRY FARM, NORTH CAROLINA

Enterprise combination and item[a]	Maximum and minimum net return and differences, by section of price map shown in Figure 2[b]				
	A	B	C	D	F
A. 1. Lowest net return and minimum difference	$14,710	$ 0	$ −373	$ 0	$ −520
2. Highest net return and maximum difference	18,586	−469	−948	−613	−722
B. 1. Lowest net return and minimum difference	0	14,982	0	−87	−1257
2. Highest net return and maximum difference	−92	20,084	−394	−1465	−1612
G. 1. Lowest net return and minimum difference	−605	0	17,124	−857	−3424
2. Highest net return and maximum difference	−1083	−843	21,295	−3741	−4054
D. 1. Lowest net return and minimum difference	0	−67	−728	13,150	0
2. Highest net return and maximum difference	−71	−911	−1462	18,287	−80
F. 1. Lowest net return and minimum difference	−321	−431	−1410	0	12,862
2. Highest net return and maximum difference	−576	−1515	−2243	−460	14,332

[a] Enterprise combinations are given in Figure 2.
[b] Net returns of each of the optimum enterprise combinations for the respective sections of the price map in Figure 2 are shown in the boxes that run diagonally from the upper left to the lower right corner; the figures outside the boxes show the maximum and minimum amount by which net return would fall below optimum if the specified enterprise combinations were selected in place of the most profitable one.

Compared with the original, the adjusted or modified price map provides a much more stable guide to production decisions in the face of price changes without materially reducing income possibilities. Actually, optimum production is likely to be more stable than this analysis indicates as a result of positive correlation between variations in prices of milk and labor and between those two items and other factors and alternative products. Although this analysis is oriented to the question of what it would "pay" farmers to do in a given situation, the adjusted price map may well be a more accurate description of what farmers are likely to do when faced with the specified conditions than is any smooth and continuous function.

In Figure 2 it can be seen that actual price-wage combinations in seven of the last nine years fell in section B of the price map. In 1954, on farms of this size the most frequent number of cows was about 24 and the harvested forage was usually produced on the farm. This analysis shows that, under the price and wage conditions that did exist, it would have been profitable to expand the dairy herd to 42 cows, and buy rather than produce the harvested forage. Empirical data show that during this period size of herds and milk output did increase rapidly. In the absence of base-quantity pricing plans, production likely would have increased more than it actually did.[6]

Dairy Farm with Tobacco Allotment of Eight Acres

This farm situation is identical with the preceding one except that there is a tobacco allotment of eight acres. The analytical procedure used in this case is the same as that employed in the other. This particular case is selected because of the very large number of small sections in the original price map—showing that very small changes in wage and milk price change the optimum enterprise combination. However, in many situations it was again found that the loss in net return, if optimum enterprise combination is not changed in response to price-wage changes, is not very large. The initial results of the programming and price mapping are shown in Table 4 and Figure 3. In the original price map there are 28 optimum enterprise combinations. Following the procedures used in the preceding case, the sections of the adjusted price map are expanded, and the number is reduced to 11 without materially reducing the income opportunities (Figure 4). An additional adjustment, in the activities of the enterprise systems that lie above the horizontal line in Figure 4, was to arbitrarily delete the tobacco production, which in each case was one acre or less. It was decided that the linearity assumption with respect to technical coefficients is questionable and that there are other practical reasons why this activity would not be carried on at such a small scale.

[6] Faris and McPherson, Technical Bulletin No. 136 (in process of publication).

Despite the fact that the number of enterprise systems is reduced from 28 to 11, and that among those remaining the differences in physical characteristics appear to be rather sizable, the income possibilities would be reduced very little if a number of the remaining systems were eliminated. For example, as shown in Table 5, the maximum by which net returns of enterprise combinations A and D would fail to produce optimum net return in section B of the price map would be $91 and $274 respectively, even though the milk price in section B varies from a low of $5.62 to a high of $6.01 per hundredweight. Combinations Z and B would fall below maximum net income by zero to $48 and zero to $115 respectively in section D of the price map. A similar situation exists among a number of the other enterprise systems as one moves horizontally across the price map. However, vertical movements, say combination A in section G or combination G in section A, show quite large differences in the maximum extent by which net incomes could fall below the optimum level.

TABLE 4. SUMMARY OF LEVELS OF ACTIVITIES SELECTED IN OPTIMUM ENTERPRISE COMBINATIONS, VARYING MILK PRICE AND WAGE RATE, INITIAL PROGRAMMING PROCESS, 110-ACRE DAIRY-TOBACCO FARM, NORTH CAROLINA

Enterprise combination[a]	Numbers and acres of enterprises in optimum combinations[b]				
	Cows number	Hens thousands	Tobacco acres	Corn acres	Alfalfa acres
A	38	4.3	8.0	22.4	0
B	41	4.1	8.0	26.1	0
C	43	4.1	8.0	23.8	0
D	50	3.8	8.0	11.2	0
E	43	4.1	1.0	30.8	0
F	41	4.1	1.0	33.1	0
G	36	4.4	.8	27.7	0
H	37	4.3	.8	29.0	0
J	43	4.1	.7	21.3	0
K	43	4.1	.8	25.9	0
L	43	4.1	.7	21.3	0
M	31	4.6	7.9	26.2	19.7
N	27	4.7	.9	32.3	24.6
O	25	4.8	.6	25.3	15.3
P	24	4.8	.6	25.8	18.4
Q	19	4.8	.6	27.5	30.8
R	19	4.8	.9	27.1	30.9
S	24	4.8	.6	25.7	18.4
T	24	4.8	1.0	32.1	30.3
U	24	4.8	7.9	26.2	31.5
V	24	4.8	7.9	26.2	32.0
W	24	4.8	7.9	25.3	30.5
X	24	4.8	7.9	18.4	18.3
Y	32	4.5	7.9	15.9	0
Z	56	3.6	8.0	0	0
AA	53	3.7	1.0	11.2	0
BB	48	3.9	.8	16.1	0
CC	59	3.4	1.0	0	0

[a] See Figure 3 for price map of combinations of milk price and wage rate.
[b] Acreage of forage produced and consumed on the farm by the dairy herd is not shown.

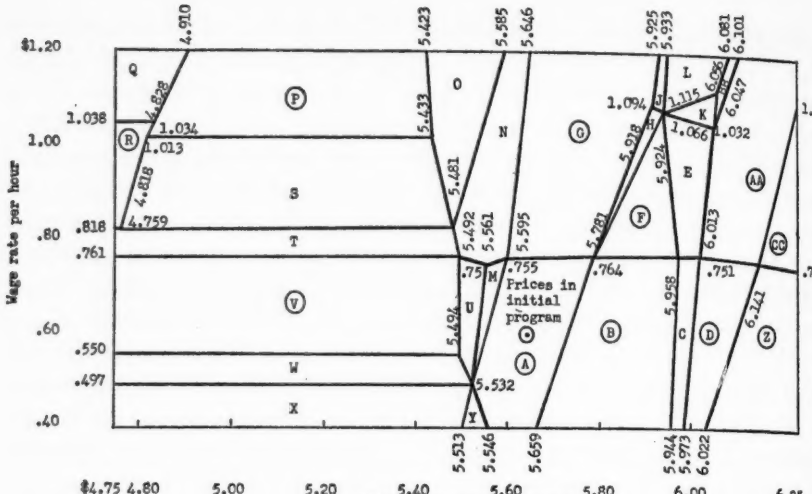
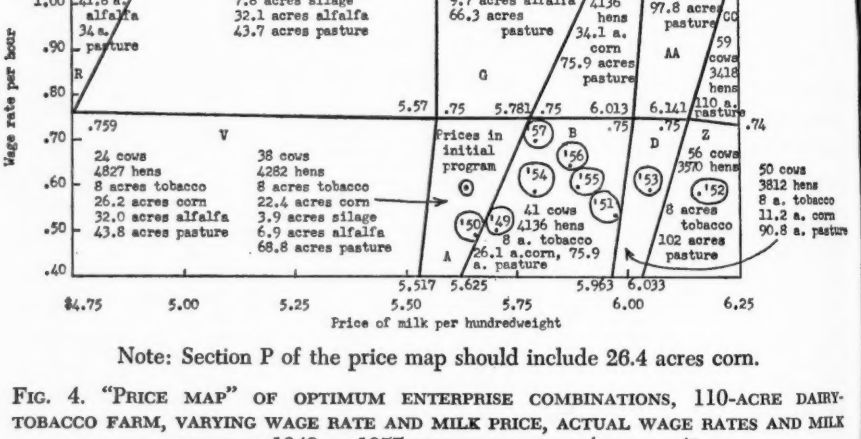


FIG. 3. "PRICE MAP" OF OPTIMUM ENTERPRISE COMBINATIONS WITH VARYING PRICE OF MILK AND WAGE RATE, 110-ACRE DAIRY-TOBACCO FARM, NORTH CAROLINA (ORIGINAL)[a]

[a] The enterprise combinations selected to develop the adjusted price map shown in Figure 4 are circled. Activities in each enterprise combination are given in Table 4.

A number of empirical items of interest may be observed at this point. At recent average wage rates, the milk price-wage combination faced by



Note: Section P of the price map should include 26.4 acres corn.

FIG. 4. "PRICE MAP" OF OPTIMUM ENTERPRISE COMBINATIONS, 110-ACRE DAIRY-TOBACCO FARM, VARYING WAGE RATE AND MILK PRICE, ACTUAL WAGE RATES AND MILK PRICES IN 1949 TO 1957, NORTH CAROLINA (ADJUSTED)[a]

[a] Actual prices shown are annual average for North Carolina, Federal-State Crop Reporting Service, 1957 estimated by adjusting average of first four months for seasonal pattern. See Figure 3 for original price map from which this adjusted one was developed.

TABLE 5. MAXIMUM AND MINIMUM NET RETURN FROM OPTIMUM ENTERPRISE COMBINATIONS AND DIFFERENCES WHEN ENTERPRISE COMBINATIONS ARE NOT CHANGED IN RESPONSE TO CHANGES IN MILK PRICE

TABLE 5. MAXIMUM AND MINIMUM NET RETURN FROM OPTIMUM ENTERPRISE COMBINATIONS AND DIFFERENCES WHEN ENTERPRISE COMBINATIONS ARE NOT CHANGED IN RESPONSE TO CHANGES IN MILK PRICE AND WAGE RATE, 110-ACRE DAIRY-TOBACCO FARM, NORTH CAROLINA

Enterprise combination and item[a]	Maximum and minimum net return and differences by sections of price map shown in Figure 4[b]										
	A	B	D	Z	V	R	P	G	F	AA	CC
A. 1	[$16,883]	$ 0	$ −53	$ −167	$ 0	$−1066	$ 0	$ 0	$ 0	$ −53	$ −216
2	[19,989]	−91	−216	−518	−1066	−2656	−2270	−1522	−1460	−1731	−1496
B. 1	0	[17,572]	0	−57	−29	−1342	−64	0	0	0	−115
2	−64	[21,235]	−115	−350	−1342	−2980	−2532	−1624	−1433	−1650	−1384
D. 1	−152	0	[18,440]	0	−391	−2354	−411	−152	0	0	0
2	−411	−274	[21,550]	−117	−2354	−4029	−3398	−2009	−1474	−1484	−1210
Z. 1	−351	−38	0	[19,042]	−670	−3111	−724	−351	−48	0	0
2	−724	−494	−48	[22,643]	−3111	−4866	−4113	−2403	−1639	−1568	−1222
V. 1	0	−137	−599	−818	[15,057]	0	0	0	−233	−599	−925
2	−233	−654	−925	−1442	[19,617]	−1510	−1409	−1867	−1949	−2475	−2237
R. 1	−400	−728	−1199	−1582	0	[12,958]	0	−268	−728	−1023	−1582
2	−1574	−2429	−2624	−3347	−1574	[15,057]	−400	−916	−1199	−1693	−1981
P. 1	0	−204	−570	−896	0	0	[13,346]	0	−204	−540	−896
2	−1182	−1699	−1863	−2487	−1045	−101	[16,883]	−458	−570	−1089	−1242
G. 1	0	0	−141	−328	0	−641	0	[14,629]	0	−25	−328
2	−1209	−1361	−1449	−1839	−2017	−987	−896	[17,572]	−141	−364	−558
F. 1	0	0	0	−158	−107	−1099	−107	0	[16,002]	0	−158
2	−1221	−1192	−1249	−1542	−2395	−1547	−1355	−191	[18,440]	−229	−338
AA. 1	−249	0	0	0	−565	−2258	−565	−59	0	[16,200]	0
2	−1690	−1544	−1179	−1219	−3692	−2950	−2700	−708	−249	[19,042]	−61
CC. 1	−444	−17	0	0	−874	−2956	−874	−208	−79	0	[17,617]
2	−1974	−1769	−1222	−1165	−4390	−3771	−3453	−1086	−444	−122	[19,676]

[a] Enterprise combinations are given in Figure 4. Number *one* shows lowest net return and minimum differences, number *two* shows highest net return and maximum differences.

[b] Net returns of each of the optimum enterprise combinations for the respective sections of the price map in Figure 4 are shown in the boxes that run diagonally from upper left to the lower right corner; the figures outside the boxes show the maximum and minimum amount by which net return would fall below optimum if the specified enterprise combinations were selected in place of the most profitable one.

farmers is near the horizontal line as shown in Figure 4. Undoubtedly, on many farms, technical coefficients are likely to place the horizontal line at a level below the 75 cents to 76 cents wage rates and/or wages are likely to be above average. Under these circumstances the marginal value of the acreage allotment falls to zero and the tobacco allotment would be underplanted. In recent years many farmers in this area have actually eliminated the tobacco enterprise and apparently many others have underplanted their allotments. It is of special interest to note that, within the price-wage limits considered in this analysis, the rising *cost* of *labor*, rather than the rising *price* of *milk* and increasing number of cows, is the effective factor in the reduction in tobacco acreage on dairy farms. Another item of interest is the observation that enterprise systems quite different in physical characteristics operate along side of one another for years. It may very well be that the differences in their income possibilities are not very great.

Price-Output Relationships

From the price maps presented in this study one can construct a milk supply schedule of the individual farm that shows the quantity of milk that it would pay to produce as a function of price with wage at any specified rate between 40 cents and $1.20 per hour. Milk supply as a function of price, with a wage rate of 60 cents and based on data given in Figure 4, is given in Figure 5.[7] Changes in production per cow are not taken into account in this illustration. This discontinuous function, although used in this analysis to show what it would pay any farmer to do under the given circumstances, might very well provide a more accurate description of actual producer behavior than does any smooth and continuous function. Further study of this question would be worthwhile and interesting.[8]

Another important point is that the price maps in this analysis show the changes in the output of other products as well as changes in output

[7] Also, a schedule of the demand for labor, on the individual farm, as a function of wage rate and/or milk price could be constructed in a similar fashion. In this milk supply function, the changes are based on movements from an initial situation in which there are dairy facilities for 24 cows and no existing poultry facilities; when facilities are actually expanded, the supply functions would be changed somewhat. Especially, the rate of response to reductions in price compared with increases in price would show larger quantities at any given price because of the changes in the variable expense function.

[8] Another illustration of a firm's product supply function derived in a similar manner is discussed in: Arvid C. Knudtson and Willard W. Cochrane, "A Supply Function for Flax at the Firm Level," *Journal of Farm Economics*, Vol. 40, No. 1, February 1958, pp. 117-123. The note by Knudtson and Cochrane came to our attention after this article had been prepared.

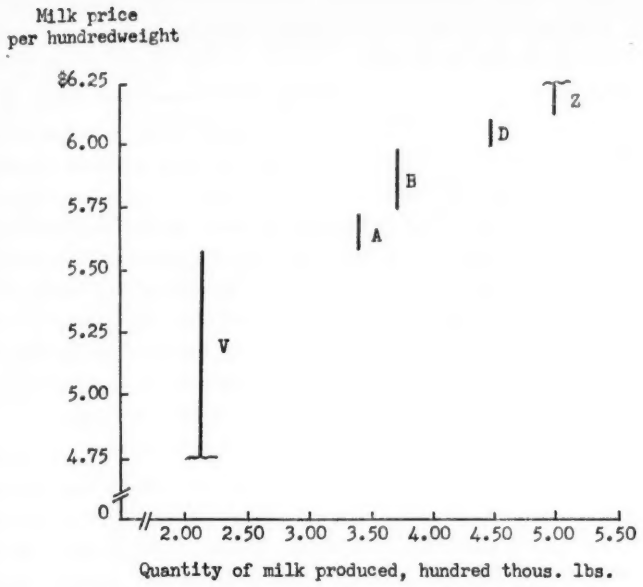


FIG. 5. MILK PRODUCTION AS A FUNCTION OF PRICE OF MILK, DAIRY FARM WITH TOBACCO, NORTH CAROLINA[a]

[a] Derived from Figure 4 with a wage rate of 60 cents. Reading from left to right the quantities of milk produced are those in sections V, A, B, D, and Z respectively of Figure 4.

of milk in response to changes in price of milk. This analysis demonstrates quite clearly the interdependence among enterprises in response to changes in price of any one product. This point merits special consideration in the formulation of farm price and production programs and illustrates an important fallacy in a commodity by commodity approach.

Summary

In a recent study of dairy farms in North Carolina, linear programming, with wage rate and milk price as variables, was used to determine optimum enterprise combinations for given wage rates and milk prices. In a number of circumstances the optimum enterprise combinations were so unstable, i.e., the ranges over which wages and prices could vary without changing the optimum combination of enterprises were so narrow, that the practical value of the results as guides to farmers was subject to considerable question. Consequently, using price mapping procedures, the study was extended to cover continuously a wide range of wage-price combinations. This procedure made it possible to determine by how much net return would fall below optimum if given enterprise combinations

were continued rather than changed to the new optimum in the face of wage-price changes. In this paper selected results of this extension of the study are described and discussed.

The ranges of wage rates and milk prices considered were \$0.40 and \$1.20 per hour and \$4.75 to \$6.25 per hundredweight, respectively. The results of the analysis of a 110-acre dairy farm, first with no tobacco allotment and then with an allotment of eight acres of tobacco, illustrate the questions considered and the procedures used. In the initial analysis of the case that had no tobacco allotment, eight optimum combinations of enterprises appeared. When modified, this number was reduced to five with appropriate increases in size of the various sections of the price map and without materially reducing the income opportunities. In the case in which there was a tobacco allotment, there was a much more dramatic reduction in optimum combinations of enterprises, from an initial number of 28 down to 11. Even after this large reduction, in several of the remaining situations the loss, as a result of not shifting from one optimum to the new optimum in the face of price-wage changes, would be little more than \$100 or \$200. Further evidence that the cost of choosing nonoptimum combinations of enterprises may be lower than the initial relatively "unstable" results indicate, is given by the fact that in some cases enterprises that do not appear at all in the optimum combinations could be substituted for one that does appear, with only small reductions in income possibilities. In the cases studied here, the substitution of small grain and lespedeza for alfalfa would lower net return by only small amounts in average situations; undoubtedly, there are many cases in which such a change would bring no reduction. It is believed that the results as modified provide a much more practical guide to farmers and a more accurate description of actual producer behavior than do the initial, unmodified results.

Although the primary aim of this article is to stimulate interest in and illustrate the use of particular analytical procedures, a number of empirical items of interest are mentioned throughout the article—such as the fact that tobacco does not appear in the optimum combination of activities when labor cost goes above 75 cents to 76 cents per hour, while at lower wage rates milk prices can vary between \$4.75 and \$6.25 per hundredweight without changing the optimum tobacco acreage.

The price mapping results provide product supply schedules of the individual firm for the product (or products) of which the price is varied. In addition, the price mapping procedure shows the effects of changing the price of one product upon the output of all other products of the farm.

CHANGES IN COTTON ACREAGE IN THE SOUTHEAST—IMPLICATIONS FOR SUPPLY FUNCTIONS*

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CONTRARY to expectations, the removal of cotton acreage allotments and marketing quotas from 1943 to 1950 was followed by a decrease in cotton production. Planted and harvested acres declined while yield per acre showed little deviation from trend, so the decrease in production may be attributed mainly to changes in acreage.[1] Nonfarm employment opportunities expanded, especially in the Southeast where cotton is a labor-intensive crop and wages for cotton labor were relatively low. It has been suggested that alternative income opportunities together with military inductions drew labor from cotton production, and the decline in production in the Southeast was the result of this drain of manpower.[2]

The data used to support this explanation are census figures on regional farm employment, wage rates and off-farm migration and military inductions. However, the limitations[3] on these data cast considerable doubt on its validity. During the 1930's there was much "underemployment" on farms. Only if actual hours used on cotton production and hours available for use were approximately equal could a reduction in available hours cause a reduction in cotton acreage.

Figure 1 shows annual rates of change in a four-state index of labor hours used in cotton production from 1935 to 1955; changes in three-state indexes of farm employment and farm population are also shown for comparison.[4] Labor hours show a high degree of variation which is inde-

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** The author is indebted to Drs. Kenneth L. Bachmann and Glen T. Barton of ARS for valuable suggestions. The author alone is responsible for any errors.

[1] See M. J. Brennan, *Cotton Production Response with Special Application to the Southeast*, ARS, U.S. Department of Agriculture, Washington, D.C., April, 1958.

[2] See James H. Street, "The 'Labor Vacuum' and Cotton Mechanization," *Journal of Farm Economics*, Vol. 35, August 1953, p. 381, for reference to this hypothesis.

[3] The data omit movements between census years. Wage differentials refer to the hired labor force only. Migration and selective service data refer to regions only—not to cotton farms. Even if migration referred to movements of persons out of cotton farms, this would not necessarily imply a decrease in the number of hours supplied for cotton production.

[4] The states included are South Carolina, Georgia, Alabama and Florida. Florida is omitted from the employment and population indexes because it produces less than 1 per cent of cotton grown in the region. The index of labor hours is from unpublished estimates of labor requirements for cotton by FERD, ARS, USDA (1951-55 preliminary). The farm employment index was made available by the Agricultural Estimates Division, AMS, USDA from unpublished data. Farm population

pendent of variations in farm employment or population. The reason for this independence is suggested by Figure 2, which depicts labor hours used in cotton production annually and minimal and maximal estimates of hours available for cotton production. The minimal estimate is for Census of Agriculture years and the maximal for Census of Population years.[5] If hours available exceed hours used, there is a "surplus" which can be removed without exerting a great influence upon acreage. Figure 2 indicates that, at least prior to 1948, available hours greatly exceeded hours actually used. Though the estimate is admittedly rough, it seems unreasonable to suppose that so large a difference can be accounted for by errors in the estimates of available hours.

No doubt wartime expansion of nonfarm employment did "pull" available hours from cotton production in the Southeast. Nevertheless, no significant correlation could be found between cotton acreage by states and (1) manufacturing employment, (2) total nonfarm employment or (3) manufacturing employment plus military inductions by states. Furthermore, no relation appears between changes in farm population and changes in cotton acreage by intra-state census economic areas. These results when combined with those of Figure 2 indicate that the off-farm movement of persons during the period cannot be considered as an adequate explanation of the decrease in cotton acreage.

Crop Substitution in Response to Price

The response of crop acreage to relative prices provides a more adequate explanation of the behavior of cotton acreage in the period 1942-48. Given the conditions of a free market, it is plausible to formulate a price expectation function for farmers which depends upon past variables. When supports are in effect, however, cogent arguments can be advanced

data were taken from Table 2 of *Farm Population, Annual Estimates by States, Major Geographic Divisions, and Regions, 1920-50 and for the United States, 1910-50*, AMS, USDA, Washington, D.C., November, 1956.

[5] The minimal estimate includes seasonally adjusted figures on operators, hired workers and unpaid members of the operators' families who worked 15 hours or more during the census week on cotton farms by states. Number of persons was converted to hours as follows: Full-time workers are assumed available for 50 hours per week for 10 weeks in preharvest and 10 weeks in harvest season. Part-time workers are assigned 30 hours per week for 20 weeks. Full-time workers include operators under 65 years of age who worked less than 100 days off the farm and all hired workers. Part-time workers are operators 65 years of age or over and members of the operators' families. The maximal estimate consists of hired seasonal workers plus the farm population 15 years or over, in those countries for which 20 per cent or more of harvested acreage is devoted to cotton. All males between 20 and 64 years of age are considered full-time workers; all others are part-time. The "true" number of available hours probably lies between these two estimates and closer to the minimal estimate. See Brennan, *op. cit.*, p. 12 for a more complete discussion of these estimates.

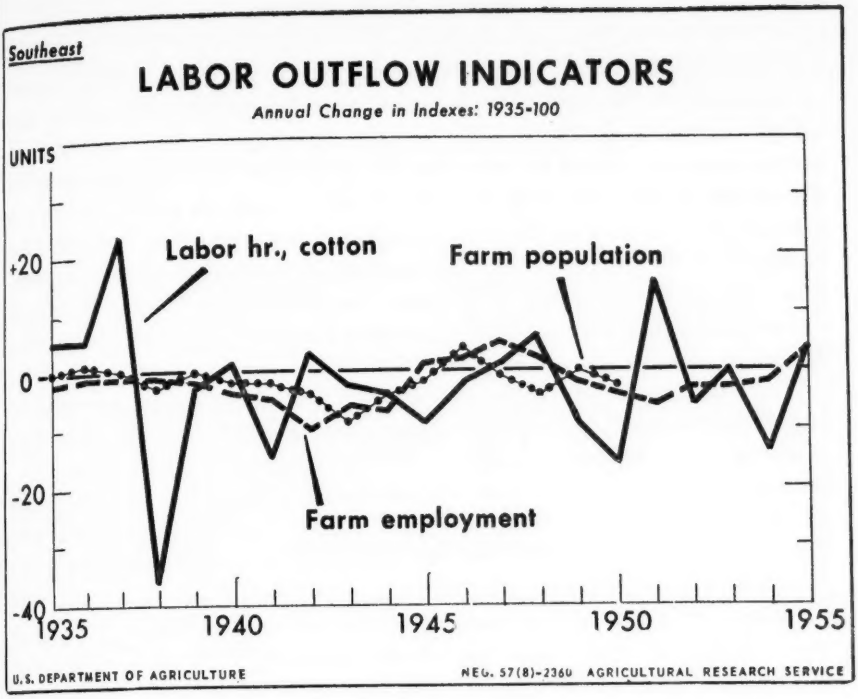
Southeast
LABOR OUTFLOW INDICATORS
Annual Change in Indexes: 1935-100
UNITS
+20
0
-20
-40
Labor hr., cotton
Farm population
Farm employment
1935
1940
1945
1950
1955
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FIG. 1

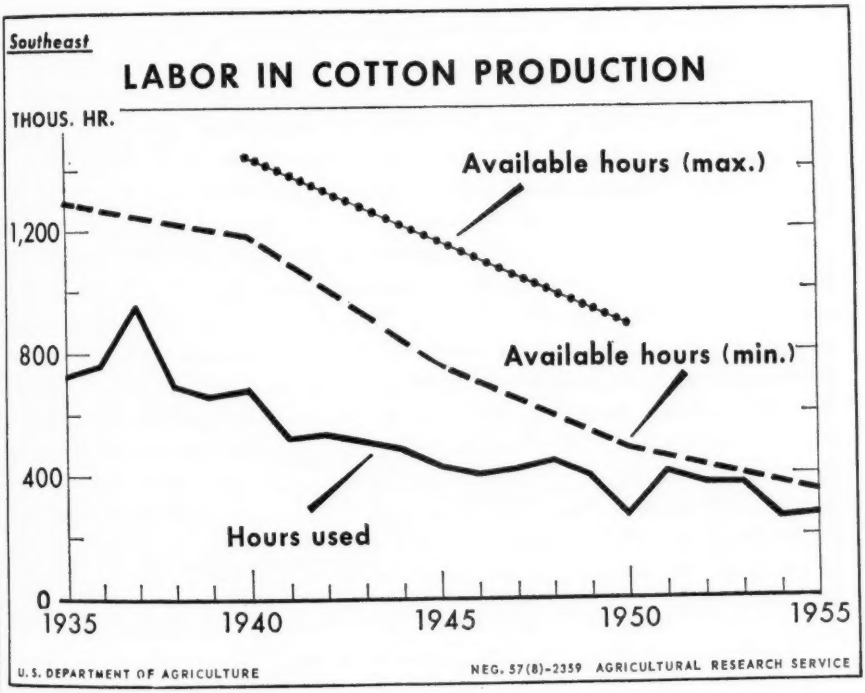
Southeast
LABOR IN COTTON PRODUCTION
THOUS. HR.
1,200
800
400
0
Available hours (max.)
Available hours (min.)
Hours used
1935
1940
1945
1950
1955
U.S. DEPARTMENT OF AGRICULTURE
NEG. 57(8)-2359 AGRICULTURAL RESEARCH SERVICE

FIG. 2

for choosing the current support price, current price received or lagged price received. We shall assume the expected price determining harvested acreage is about equal to the actual price received by farmers (harvested acreage related to price lagged one year does not yield notable differences in the conclusions). The choice of current prices received is justified on the ground that they exceeded support prices in each year except 1944. Given the elements of certainty provided by expanding wartime and postwar demand conditions, it is plausible to assume that farmers' expected prices approximated current actual prices more closely than either the support or the lagged actual prices.

If relative prices were the dominant force operating on acreage decisions, we should observe that the percentage of total cropland devoted to cotton is negatively correlated with the ratio of the price of a substitute crop to the price of cotton. We must observe also that the percentage of cropland devoted to the substitute crop is positively correlated with this price ratio. For each of the five Southeastern states the acreage harvested for the nine most important crops was tabulated (wheat, corn, oats, soybeans, cowpeas, hay, tobacco, peanuts and cotton). In terms of cropland harvested, corn and hay were important potential substitutes throughout most of the region; peanuts were especially important in Georgia and Florida and tobacco in North Carolina. From annual state data, correlations were run between the ratios of harvested cotton acres to total acres harvested for all nine crops and the ratios of prices received for potential substitutes to the prices received for cotton. Correlations were also run between the ratios of acreages of substitutes to total acres and the corresponding ratios of prices of substitutes to cotton prices. The correlation coefficients for each state are shown in Table 1 for the prewar years (when acreage restrictions were in effect) and for the years when allotments and quotas were absent.

Before 1941 there was little response of acreage to price. Except for the corn-cotton relation in Florida and North Carolina, the signs of all the coefficients reflect crop substitutions during the years 1942-48. But the values of the coefficients are small. Hay and peanuts are the strongest substitutes, with correlation coefficients in the neighborhood of .8 and .9. The phenomenal rise of the price of livestock during World War II apparently accounts for the switch from cotton to hay. From 1940 to 1950 there was a correlation of .8 between annual average prices received by farmers for meat animals and acreage of hay in the Southeast; between prices received for dairy products and hay acreage, the coefficient is .76. Since 1940 the number of livestock on farms in the Southeast has increased steadily.[6] If data were available on an annual basis, one might

[6] Bureau of Agriculture Economics, *Will More Forage Pay?* USDA Misc. Pub. 702, November 1949.

TABLE 1. INDICATORS OF CHANGES IN COTTON ACREAGE IN RESPONSE TO RELATIVE PRICES

Items correlated	Period[2]	Correlation coefficients
Alabama:		
Price of corn and acreage of:		
Corn	1933–41	−.25
	1942–48	+.22
Cotton	1933–41	+.22
	1942–48	−.23
Price of hay and acreage of:		
Hay[3]	1933–41	+.20
	1942–48	+.80
Cotton	1933–41	−.16
	1942–48	−.77
Georgia:		
Price of corn and acreage of:		
Corn	1933–40	−.13
	1941–48	+.46
Cotton	1933–40	+.11
	1941–48	−.39
Price of hay and acreage of:		
Hay[3]	1933–40	+.27
	1941–48	+.92
Cotton	1933–40	−.21
	1941–48	−.78
Price of peanuts and acreage of:		
Peanuts	1933–40	+.33
	1941–48	+.84
Cotton	1933–40	−.47
	1941–48	−.91
Florida:		
Price of corn and acreage of:		
Corn	1933–41	+.02
	1942–48	−.01
Cotton	1933–41	−.06
	1942–48	−.08
Price of peanuts and acreage of:		
Peanuts	1933–41	−.12
	1942–48	+.82
Cotton	1933–41	−.14
	1942–48	−.81
South Carolina:		
Price of corn and acreage of:		
Corn	1933–41	+.18
	1942–48	+.51
Cotton	1933–41	+.34
	1942–48	−.68
North Carolina		
Price of corn and acreage of:		
Corn	1933–40	−.42
	1941–48	−.57
Cotton	1933–40	+.06
	1941–48	−.39
Price of tobacco and acreage of:[2]		
Tobacco	1933–40	−.24
	1941–48[4]	+.77
Cotton	1933–40	+.13
	1941–48[4]	−.79
Price of hay and acreage of:		
Hay[3]	1933–40	+.20
	1941–48	+.92
Cotton	1933–40	−.44
	1941–48	−.87

(Footnotes on next page)

expect to find that there was also a substitution of cropland devoted to pasture for cotton acreage. Census of Agriculture data for 1940, 1945 and 1950 indicate that cropland in pasture has risen continuously in the southeastern states. The shortage of fats and oils during the war and the consequent high price of peanuts probably accounts for the substitution of peanuts for cotton in Georgia and Florida.

Though the samples are smaller than most samples with which economists work (seven and eight observations), using the t test all the coefficients except those for corn and cotton in South Carolina were found to be statistically significant at the 5 per cent level. The economic forces operating at the time (described above) tend to support the conclusions; the confidence placed in the estimates is based on both the economic reasoning and the statistical properties of the estimates.

To obtain an idea of the magnitude of the change in cotton acreage in response to changes in the prices of substitute crops, cross price elasticities have been computed. When two crops are substitutes in production, their price cross elasticities of supply are negative. If the cross elasticity of cotton acreage with respect to the relative price of another crop turns out negative, its value provides evidence of the percentage change in cotton acreage in response to a given percentage change in the price of the substitute crop relative to the price of cotton.

Table 2 shows the cross elasticities of harvested cotton acres with respect to the prices of hay, peanuts, tobacco and corn, each deflated by the price of cotton for the war and postwar years covered in Table 1. Elasticities were computed at the mean values of prices and acres from multiple linear regressions. The negative values give further evidence of crop substitution, but the degree of substitution appears to be relatively weak between cotton and tobacco and between cotton and corn. In summary, the data presented in Tables 1 and 2 give support to the hypothesis that the dominant force operating to decrease cotton acreage when restrictions were removed is to be found in the substitution of hay and peanuts (and perhaps pasture) for cotton in response to relative price changes during this period.

[1] Prices deflated by price of cotton. Acreage figures are harvested acreages of particular crops as percentages of total harvested acreages of all principal crops.

[2] Choice of period to be covered was dictated partly by factual information and partly by formation of scatter diagrams relating acreage and price received, which indicate that substitution began in Georgia and North Carolina in 1941 and in the other states in 1942. Another reason for starting with 1941 for these two states is the lower degree of underemployment and the underplanting of cotton, peanuts, and, in some instances, tobacco, relative to total cropland. Somewhat higher correlation coefficients were obtained by omitting the 1942 observations in Florida, South Carolina, and Alabama.

[3] Excludes alfalfa, clover-timothy, and lespedeza, which are not subject to year-to-year variations. In Georgia and Alabama, excludes peanuts for hay in 1944–48 because significant part of acreage is hogged-off—information not available on peanuts for hay before 1944.

[4] 1947 omitted because it shows as extreme deviation in scatter diagram. *Agricultural Statistics*, U. S. Department of Agriculture (annual), and unpublished data in the U. S. Agricultural Marketing Service.

TABLE 2. CROSS ELASTICITIES OF COTTON ACREAGE WITH RESPECT TO PRICES OF SUBSTITUTE CROPS[1]

Crops	Elasticities
Hay:	
Alabama	−.84
Georgia	−.47
North Carolina	−.64
Peanuts:	
Georgia	−.31
Florida	−1.54
Tobacco:	
North Carolina	−.22
Corn:	
South Carolina	−.09

[1] Simple linear regressions on the deflated prices of hay, peanuts, and corn were used for Alabama, Florida, and South Carolina, respectively. For Georgia and North Carolina, multiple linear regressions of cotton acreage on the prices of two substitute crops were used. *Multicollinearity* was found to exist in the regression for North Carolina when the deflated prices of hay and tobacco were used as explanatory variables. Although this means that the separate influences of the two explanatory variables cannot be ascertained, the signs of the coefficients are still relevant. Therefore, they were included in the tabulation above.

Implications for Aggregate Supply Functions

The results found for the war and postwar years contain certain implications for the construction of aggregate supply functions for individual crops. Recent discussions on agricultural production have emphasized our lack of knowledge about aggregate supply response.[7] Most writers have not really questioned our quantitative knowledge of supply functions for individual products but have stressed the gaps in our knowledge concerning changes in the supply of farm products as a whole. The factors connected with aggregate technological change and long-run input-output relationships have received most attention.

The few attempts to construct United States supply functions for single farm products have typically used average U.S. data on acreage, prices, etc.[8] Furthermore, few studies have included the prices of other crops or the prices of inputs in their investigations. This type of averaging may lead to sufficiently accurate results for some commodities. But many crops are grown over wide areas within which alternative crops, soil and climate, wage rates, technological conditions, etc. show enough differences

[7] *Cf.* T. W. Schultz, "Reflections on Agricultural Production, Output and Supply," *Journal of Farm Economics*, Vol. 38, August 1956, pp. 748-762; G. L. Johnson, "Some Facts and Notions about the Supply Function for Agriculture," unpublished paper presented at the Conference on Adjusting Commercial Agriculture to Economic Growth, Chicago, Ill., March 18-19, 1957.

[8] See M. Nerlove, "Estimates of Elasticities of Supply of Selected Agricultural Commodities," *Journal of Farm Economics*, Vol. 38, May 1956, pp. 496-509 for discussion of these attempts at supply construction.

to exert diverse production responses in different regions. Since these differences are concealed by average figures for the U.S. as a whole, it is likely that the quantitative predictions these data yield are unreliable.

These considerations suggest that a more fruitful approach to the problem of supply response can be found in more micro-economic research (other than studies of individual farms). The total U.S. supply could then be built up from several functions—one for each region containing the variables relevant to that region. Ideally each region would be defined in terms of homogeneity of crop substitutes, technology, climate, etc. In the case of cotton, probably 10 economically defined regions would be required. Of course, data must be available by economic regions, and our present geographic classifications prevent the immediate realization of this ideal. However, several government agencies are compiling data by states and census regions for some commodities.[9]

As a step in this direction, cotton acreage in the U.S. has been divided here into three geographic categories: the Southeast, the Mississippi Delta, and the Southwest.[10] It must be realized that some diversity persists within each of these regions. For each region a tentative cotton acreage-response function has been constructed for the period 1905-32 (prior to price supports). Acreage in each region is expressed as a function of the expected price of cotton, the expected prices of selected substitute crops, and trend. The expected price of each crop is assumed to depend upon two past prices and is computed from J. R. Hicks' elasticity of price expectation. This is equivalent to the assumption that the expected percentage change in price in the current year relative to the price in the preceding year is proportional to the percentage price change last year relative to the price two years ago.[11]

Past prices are season average prices received by producers, weighted in each state by acreage in that state, and deflated by an index of prices received for all farm products. The choice of substitute crops was deter-

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[9] The 1954 Census of Agriculture contains a special report entitled *Cotton Producers and Cotton Production*, Vol. 3, Part 9, Chap. II in which data are classified by 10 subregions.

[10] The Southeast includes North Carolina, South Carolina, Georgia, Alabama and Florida. The Delta consists of Louisiana, Arkansas, Mississippi, Tennessee and Missouri. The Southwest includes Texas, Oklahoma, California, Arizona, and New Mexico after 1921.

[11] Let P_t^* represent the expected price in year t and P_t the actual price. The elasticity of price expectation, α, is defined as

$$\frac{P_t^* - P_{t-1}}{P_{t-1}} = \alpha \frac{P_{t-1} - P_{t-2}}{P_{t-2}},$$

where α is a constant. P_t^* is estimated from this relation after α has been determined by least squares. To determine α, the above expression is integrated to obtain a logarithmic relation in which α is a parameter.

mined by the number of acres devoted to various crops in each state. The important potential crop substitutes in the Southeast are corn, hay, tobacco and peanuts. Corn and hay are important in the Delta region, and in the Southwest corn, wheat and oats. In the Southwest substitute crops in California, Arizona and New Mexico were ignored because these states produced less than 3 per cent of total production in that region. Grain sorghums were very important in Texas and Oklahoma but had to be omitted because the series on acreage and price did not go back beyond 1918. In general, during this period the Delta and the Southwest appear to have been more homogeneous than the Southeast with respect to substitute crops grown in various areas within the region. With the development of supplemental irrigation this may not be true today.

The acreage-response function is assumed to be approximately linear in each region. The following relations were found for the regions indicated. The partial regression coefficient for the expected price of oats is not significantly different from zero and has been omitted from the equations. Figures in the parentheses are standard errors of the regression coefficients.[12]

(1) $X_e = 12.02 + .29P_c - .05P_r - .02P_t - .10P_p - .13t,$
$R^2 = .79 \quad (\pm.097) \quad (\pm.019) \quad (\pm.009) \quad (\pm.020) \quad (\pm.058)$

(2) $X_d = 6.37 + .25P_c - .06P_r + .16t,$
$R^2 = .84 \quad (\pm.080) \quad (\pm.031) \quad (\pm.087)$

(3) $X_w = 11.76 + .48P_c - .03P_r - .07P_w + .17t.$
$R^2 = .73 \quad (\pm.151) \quad (\pm.014) \quad (\pm.031) \quad (\pm.111)$

X_e, X_d and X_w are planted acres on July 1 for the Southeast, the Delta and the Southwest, respectively, measured in millions of acres. P_c, P_r, P_t, P_p and P_w are the expected prices in cents per unit of cotton, corn, tobacco, peanuts and wheat, respectively, in each region. t is the trend variable. The relatively small values of the coefficients of substitute crops suggest that substitution of other crops for cotton occurred only when relatively large price changes were expected for the substitutes. The comparatively weak multiple correlation coefficient in the Southwest is probably due to the omission of grain sorghums.

It is interesting to compare these results with those obtained by writers who have used average data for the U.S. as a whole and have not included

[12] Using R. Frisch's bunch maps, no definite multicollinearity could be established among the explanatory variables. However, for the expected prices of corn and wheat in the Southwest the conclusions are highly uncertain. To test for the presence of autocorrelation in the residuals, the ratio of the mean square successive difference to variance was used. The hypothesis of no significant autocorrelation cannot be rejected.

the prices of substitutes in their estimation procedures. In an admirable study of the pre-1933 period, Nerlove expresses cotton acreage as a function of the expected price of cotton and trend.[13] The expected price is a weighted average of several past prices. Earlier investigations have commonly used cotton price lagged one year as the explanatory variable. Nerlove estimates the price elasticity of supply (i.e., acreage) as .67 as compared with approximately .20 derived by using price lagged on year. The estimates in this paper lie between these two. For the Southeast, the Delta, and the Southwest, the price elasticities at the mean values of cotton prices and acreages are .33, .31 and .37, respectively. The percentage of total variation in cotton acres attributed to the explanatory variables (R^2) is .59 for price lagged one year and trend and .74 for Nerlove's expected price and trend. Equations (1), (2) and (3) show R^2 values of .79, .84 and .73, respectively. The trend variable summarizes the systematic forces operating on acreage which have not been explicitly included in the equations. A reduction in its coefficient reduces our "ignorance" about the separate influences of these factors. The trend coefficients in the equations are slightly less than those obtained by Nerlove. He finds a trend coefficient of .18 as compared with a trend coefficient of .48 in the relation using price of cotton lagged one year as the explanatory variable.

This preliminary geographical breakdown into three regions shows some improvement in our ability to explain changes in cotton acreage. Though the results are not entirely satisfactory, they do point up the need for more precise formulations of acreage and production response. Progress in this direction may demand a more economically meaningful subdivision of regions. This is indicated, e.g., by the number of prices included in the acreage function for the Southeast.

A closely related consideration is the criterion for choice of potential substitutes. Though small in land coverage, truck crops play a more important role as a substitute for cotton than would be indicated by size of acres alone. Type and size of operation should also receive some weight in the choice of substitutes.

Finally, there is the problem of geographical aggregation of the regional supply functions to obtain a supply function for the U.S. Although it is impossible to present a detailed discussion of regional aggregation here, it is worth mentioning that a simple linear summation of the parameters in the equations for each region does not yield a reliable total U.S. supply function. Nevertheless, the results obtained for the war period and for the period 1905-32 emphasize the need for a comprehensive study of cotton production which takes into account the potentialities of geographic breakdowns in the U.S. data.

[13] Nerlove, *op. cit.*, p. 501.

CHANGES IN SUPPLY RESPONSE AND ELASTICITY FOR HOGS*

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POSTWAR literature indicates a renewed interest in the supply of agricultural products. Large price variations for several farm products in recent years have intensified this interest.[1] One commodity possessing a high degree of price instability, historically and particularly within the past few years has been pork. Using a simple measure of variability, the coefficient of variation, annual variations in deflated hog prices (average from October through April) increased from 16 per cent in the prewar years to 25 per cent in the postwar years.[2] A basic explanation of recent fluctuations in hog prices, particularly the drastic price drop in the fall and winter of 1955-56, has been demanded repeatedly by farmers and legislators. The authors hypothesize that due to new techniques of production the elasticity of production, and hence the elasticity supply, has increased in recent years, thus contributing to increased variation in hog prices. We present the results of an empirical study which substantiates these hypotheses.

The well-known "cobweb" theorem provides a possible theoretical framework for explaining recurring cycles in the production and price series for hogs. According to classical economic theory, price is established by equation of demand and supply functions. However, where a considerable time lag exists between the price change for a commodity and the resulting supply response, the cobweb relationship may arise. From the classic article by Ezekiel,[3] the three cobweb cases shown in Fig. 1 are derived and explained as follows: Quantity Q_1 is produced in time period 1 resulting in a price of P_1 on the demand curve. At the low price P_1, producers supply only Q_2 in time period 2. With only Q_2 supplied, price is established at P_2. Producers respond to P_2 by producing Q_3 in time period 3. But with Q_3 supplied, price falls to P_3, etc. Assuming linear functions, continuous fluctuations (case 1) occur when the demand and supply curves have the same absolute slope. Divergent fluctua-

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[1] For example see Breimyer, Harold F., "On Price Determination and Aggregate Price Theory," *Journal of Farm Economics*, Vol. 39, August, 1957, pp. 676-694.

[2] Hog prices were deflated by the Index of Wholesale Prices for this comparison. The prewar period included years 1923 to 1942, excluding the depression years 1931 to 1934 when hog prices remained abnormally depressed; the postwar period included years 1946 to 1957.

[3] Ezekiel, Mordecai, "The Cobweb Theorem," *Quarterly Journal of Economics*, Vol. 52, 1938, pp. 255-280.

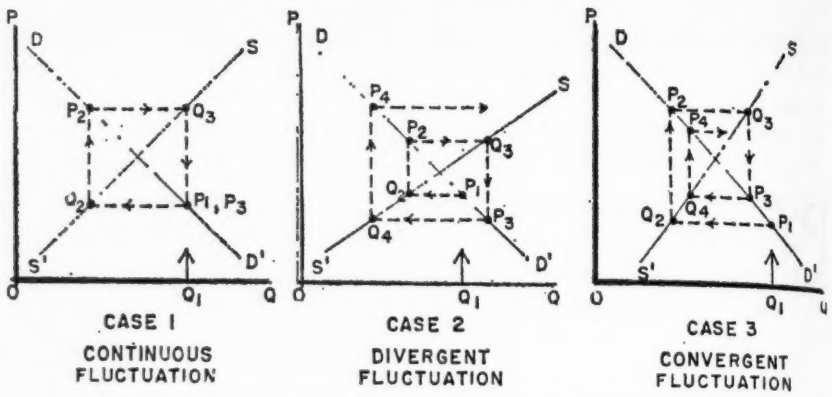

FIG. 1. THREE POSSIBLE CASES ILLUSTATING THE COBWEB THEOREM

tions (case 2) occur when the absolute slope of the demand function is greater than that of the supply function. Convergent fluctuations (case 3) occur when the absolute slope of the demand function is less than that of the supply function.

Three conditions are required for the cobweb theorem to explain the functioning of a commodity market: (a) Producers plan in period t for output in period t + 1 on the basis of prices in period t; (b) production plans, once made, cannot be changed until the following time period; (c) price must be determined by the quantity sold (i.e., by intersection of a conventional demand function and a vertical supply function). The production, demand and supply structure for hogs approximates these conditions. With regard to condition (a), limited research evidence points to "extension of current prices" as a dominant expectational model used by producers.[4] Condition (b) is approximately met since once sows are bred, relatively little can be done to increase or decrease future production.[5] Condition (c) implies no simultaneity between price and quantity within the marketing period, i.e., quantity is assumed to be predetermined. While farmers do market piggy sows and vary marketing weights in response to short-run price changes, most demand analysts have been quite successful in assuming that pork supplies are predetermined.[6]

[4] See Heady, E. O. and Kaldor, D. R., "Expectations and Errors in Forecasting Agricultural Prices," *Journal of Political Economy*, Vol. 62, No. 1, February, 1954, p. 35; Williams, D. B., "Price Expectations of Illinois Farmers," *Journal of Farm Economics*, Vol. 33, 1951, p. 23; Schultz, T. W. and Brownlee, O. H., "Two Trials to Determine Expectation Models of Farmers," *Quarterly Journal of Economics*, Vol. 56, 1941, pp. 487-496.

[5] Of course, bred sows are sometimes sold before farrowing. However, heavy price discounts on bred sows sold after the second month of pregnancy limit this possibility.

[6] For example, see Fox, K. A., *The Analysis of Demand for Farm Products*, U. S. Dept. Agr. Tech. Bul. 1081, 1953.

Evidence of a cobweb relationship in the U. S. hog market is provided in Fig. 2, where the hog-corn price ratio (defined as price of hogs per cwt. ÷ price of corn per bu.) during October, November and December (year t) is measured on the vertical axis, and spring sow farrowings (year t + 1) are measured on the horizontal axis. The gestation period for hogs is approximately four months while another six to eight months is required for feeding to market weights. Hence, pigs raised from sows bred one fall usually are sold the next fall, some 10 to 12 months later. Prices at which these hogs are marketed then are known prior to breeding time for the next spring pig crop. Under the cobweb theorem, relatively high

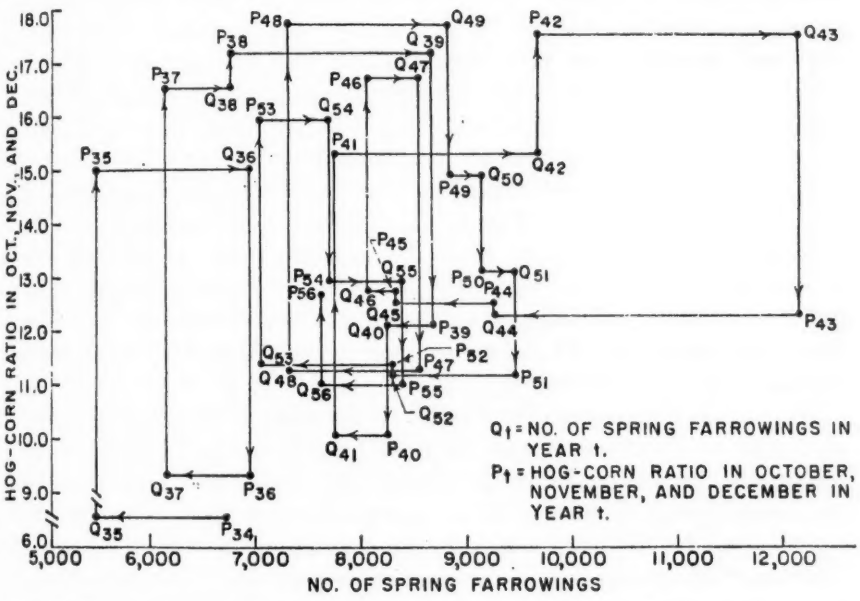

FIG. 2. EVIDENCE OF A COBWEB RELATIONSHIP IN THE UNITED STATES HOG MARKET

hog prices one fall lead to a large number of farrowings the next spring. Pigs from this large spring crop are marketed the following fall, driving hog prices downward. Low hog prices induce a smaller number of spring farrowings, which in turn lead to high hog prices the following fall, etc.

Fig. 2 indicates that, with modifications, such a process has in fact taken place. With the low hog-corn price ratio in the fall of 1934 (P_{34}), only 5,467,000 litters were farrowed in the spring of 1935 (Q_{35}). This relatively low number of farrowings resulted in a short hog supply in the fall of 1935 and a relatively high hog-corn price ratio (P_{35}). The higher hog-corn ratio (P_{35}) encouraged increased spring farrowings in 1936 (Q_{36})

which, in turn, resulted in lower hog prices and a lower hog-corn ratio (P_{36}) in the fall, etc. There is sufficient regularity in the clockwise movement of prices and quantity to suggest an underlying cobweb relationship. Of course, the pattern is disrupted by shifts in the demand and supply functions due to World War II, the Korean War and other important factors. Feed grain supplies and the prices of competing farm products probably also play a role not accounted for by this simple model. Nevertheless, the authors argue that the cobweb relationship provides a workable theoretical framework for analyzing fluctuations in price and quantity (particularly for spring farrowings) in the U. S. hog market.

It is hypothesized that the elasticity of pork production has increased over the past two decades.[7] Technical developments which might increase production elasticity include improved rations (particularly antibiotics), improved breeding and sanitation methods and new physical facilities which allow farrowing in colder weather. For example, building and heating equipment allow multiple farrowing, with more pigs born during winter months if price expectations are favorable. The expected effect of these changes in the production function are illustrated schematically in Fig. 3. Suppose that TP_1 (diagram 1, Fig. 3) is the "pre-World War II" production function for hogs while TP_2 represents the "post-World War II" production function. Curve TP_1 "flattens out" rather abruptly as the limits of facilities and skills are reached, because the elasticity of production is relatively low; TP_2 "flattens" more gradually at high input levels because of the greater elasticity.

Diagram 2, Fig. 3, provides marginal cost curves MC_1 and MC_2, associated with production functions TP_1 and TP_2, respectively. Theoretically, the supply curve of an individual firm is, aside from imperfect knowledge and uncertainty, identical with its marginal cost curve. The aggregate supply function for hogs is merely the summation of individual supply functions.[8] Diagram 3, Fig. 3, provides aggregate supply functions S_1 and S_2 paralleling the "typical firm" supply functions MC_1 and MC_2. Assuming that the demand function DD′ remains unchanged, the shift in the supply function from S_1 to S_2 leads to wider price fluctuations. Starting from quantity Q_1 and price P_1, the cobweb pattern based on supply curve S_1 is convergent (P_1, Q_2, P_2, Q_3, P_3, Q_4, etc.). Starting at the same quantity and price, the cobweb pattern based on supply curve S_2 is divergent (P_1, Q_2',

[7] Changes in the elasticity of production (and hence in the elasticity of supply) can be brought about by (1) movement along a production function and or (2) a shift in the production function.

[8] Some authors distinguish between a theoretical supply function (summation of firm marginal cost curves) and a supply "response" function (observed response in output to price and other factors). Using this distinction, the empirical functions presented subsequently would be properly termed supply "response" functions.

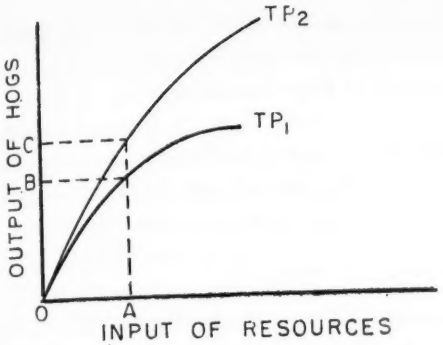

DIAGRAM 1

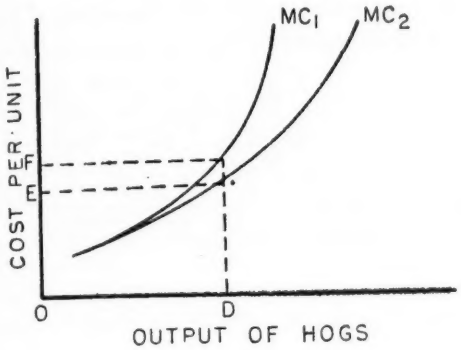

DIAGRAM 2

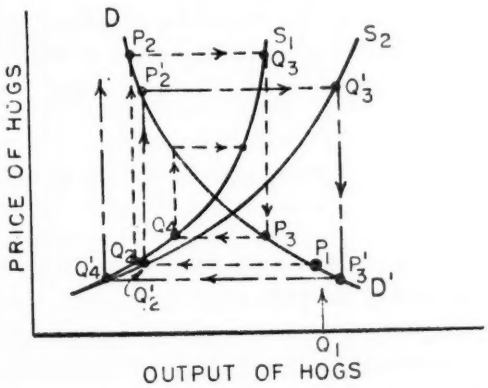

DIAGRAM 3

FIG. 3. THEORETICAL PRODUCTION FUNCTION (DIAGRAM 1), MARGINAL COST CURVES (DIAGRAM 2) AND COBWEB RELATIONSHIP (DIAGRAM 3) FOR HOGS WITH A SHIFT IN TECHNOLOGY.

P_2', Q_3', P_3', Q_4', etc.). Of course, a shift in the supply function from S_1 to S_2 need not cause a shift from the convergent to the divergent fluctuations case; the shift may only delay convergence.[9]

[9] The above discussion and graphical presentation assume a "once and for all".

Given the changes in techniques in recent years, the hypothesis is extended that these shifts in the supply function have taken place, and that, in fact, the phenomena illustrated in Fig. 3 are occurring. But in addition to this, there is evidence that the price elasticity of demand for pork also is decreasing, adding even greater impetus to "width of swings" in pork production and price. Empirical analyses of supply and demand functions are now presented which support these hypotheses.

Empirical Analysis

The total liveweight production of hogs in the United States depends directly on the number of hogs marketed and their average marketing weight. Accordingly, hog supply relationships can be divided logically into an analysis of farrowings (the main determinant of hog numbers) and an analysis of marketing weights. To obtain comparisons of supply response functions over time the analysis is divided further into two periods —1924-1937 and 1938-1956 (omitting war years, 1942, 1943 and 1944). While a more logical division with respect to time might be into prewar and postwar periods, the postwar analysis necessarily would be based on relatively short time series. The above periods were selected as a compromise.

Analysis of Spring Farrowings

Equations 1 and 2 are least-squares estimates of spring farrowing response functions in the United States for 1938-1956 (omitting 1942, 1943 and 1944) and 1924-1937, respectively. Standard errors of the

$$(1)\quad \hat{Y}_1 = -7{,}430 + \underset{(36)}{418X_1} + \underset{(11)}{66X_2} + \underset{(229)}{578X_3} \qquad R^2 = 0.93 \qquad d = 1.20$$

$$(2)\quad \hat{Y}_1 = -7{,}401 + \underset{(35)}{366X_1} + \underset{(10)}{28X_2} + \underset{(249)}{962X_4} \qquad R^2 = 0.92 \qquad d = 1.42$$

regression coefficients appear in parentheses below the coefficients. Variables in the equations are defined as follows:

$\hat{Y}_1$ = Estimated first difference in the number of spring farrowings, United States (in 1,000 litters). (The spring farrowing period extends from December, year t-1 through May, year t.)

X_1 = United States hog-corn ratio as an average of October, November and December, year t-1 (hog price in dollars per cwt. ÷ corn price in dollars per bu.).

---

shift in the supply curve as a result of technological change. Actually, the supply curve probably has been shifting gradually over time as changes in technology have occurred.

X_2 = First difference of oats, barley and grain sorghum production as a percentage of corn production, United States. That is, S_{t-1}-S_{t-2}, where S denotes oats, barley and grain sorghum production as a percentage of corn production. This variable is coded by adding a constant of 15.0 to remove negative values.

X_3 = Ratio between the average price of 500-800 pound good-choice stocker and feeder cattle at Omaha and the average United States hog price during October, November and December, year t-1 (prices in dollars per cwt.).

X_4 = Margin (in dollars per cwt.) between the average price of all feeder cattle and the average price of slaughter cattle at Chicago as an average of October, November and December, year t-1, deflated by the Index of Wholesale Prices (1910-1914 = 100).

The absolute level of the hog-corn ratio (X_1) at breeding time (October-November-December) strongly influences the direction and magnitude of changes in spring farrowings. In addition to corn production (reflected in the hog-corn ratio) Brandow[10] notes a separate influence on hog supplies exerted by the production of oats, barley and grain sorghum. When these grains comprise a relatively large proportion of the total feed grain supply, hog production tends to increase and vice versa. Variable X_2 expresses this relationship. Variables X_3 and X_4 represent alternative methods of expressing the competitive position of beef cattle and hog enterprises at the farm level. A high feeder cattle-hog ratio (X_3) tends to discourage cattle feeding relative to hog production. However, the positive sign of variable X_4 (deflated cattle margins) in equation 2 appears inconsistent with economic logic, i.e., as cattle margins increase, making cattle production more favorable, hog production is expected to decrease.

The high R^2 values for equations 1 and 2 indicate a good statistical "fit." Standard errors of the estimate for equations 1 and 2 are 3.13 and 4.11 per cent of the mean number of farrowings, respectively. In addition, the direction of change in spring farrowings is predicted correctly for every year except 1946. The Durbin-Watson d statistic[11] for equation 1 is 1.02, indicating that the hypothesis of serial independence in the residuals is rejected. When plotted, the residuals show a slight cyclical effect, which accounts for the significant test result. The d statistic for equation 2 falls in the inconclusive test range.

Since between 70 and 80 per cent of the spring farrowings in the United

[10] Brandow, G. E., *Factors Associated with Numbers of Sows Farrowing in the Spring and Fall Seasons*, Pennsylvania Agricultural Experiment Station A. E. and R. S. 7, 1956.

[11] Durbin, J. and G. S. Watson, "Testing for Serial Correlation in Least-Squares Regression II," *Biometrica*, Vol. 38, 1951, pp. 159-178.

States normally occur in the 12-state North Central region,[12] this area is subjected to separate analysis. Spring farrowing response functions 3 and 4 are computed for the North Central region for 1938-1956 (omitting 1942, 1943 and 1944) and 1924-1937, respectively.

$$(3)\quad \hat{Y}_2 = -6{,}770 + 400X_1' + 50X_2 + 726X_3' \qquad R_2 = 0.93 \quad d = 2.01$$
$$\qquad\qquad\qquad\quad (33) \qquad (9) \qquad (195)$$

$$(4)\quad \hat{Y}_2 = -6{,}621 + 316X_1' + 22X_2 + 894X_t \qquad R_2 = 0.90 \quad d = 1.75$$
$$\qquad\qquad\qquad\quad (35) \qquad (10) \qquad (248)$$

The variables are defined as follows:

$\hat{Y}_2$ = Estimated first difference in the number of spring farrowings, North Central region (in 1,000 litters).

X_1' = Chicago hog-corn ratio as an average of October, November and December, year t-1.

X_2 = Same as X_2 defined above.

X_3' = Ratio between the average price of 500-800 pound good-choice stocker and feeder cattle at Omaha and the average Chicago hog price during October, November and December, year t-1 (prices in dollars per cwt.).

X_4 = Same as X_4 defined above.

The logic for the same or similar variables was described above for the United States and is not repeated. Standard errors of the estimate for equations 3 and 4 are 3.20 and 5.20 per cent of the mean, respectively. Again, the equations correctly predict the direction of change in farrowings for every year except 1946. Nonsignificant d statistics for these two equations indicate support for the assumption of serial independence of the residuals.

Analysis of Fall Farrowings

Regression equations 5 and 6 are computed for fall farrowings in the United States for 1937-1956 (omitting 1941, 1942, 1943 and 1944) and

$$(5)\quad \hat{Y}_1 = 237.96 + 0.28X_1 + 4.00X_2 + 8.46X_3 \qquad R^2 = 0.92 \quad d = 1.70$$
$$\qquad\qquad\qquad\quad (0.09) \qquad (1.06) \qquad (2.39)$$

$$(6)\quad \hat{Y}_1 = 369.13 + 0.29X_1 + 1.38X_4 + 11.55X_3 \qquad R^2 = 0.75 \quad d = 2.45$$
$$\qquad\qquad\qquad\quad (0.08) \qquad (0.64) \qquad (4.13)$$

$$(7)\quad \hat{Y}_2 = -941.89 + 0.23X_1' + 5.46X_2 + 8.20X_3 \qquad R^2 = 0.89 \quad d = 1.27$$
$$\qquad\qquad\qquad\quad (0.12) \qquad (1.39) \qquad (2.79)$$

$$(8)\quad \hat{Y}_2 = -390.11 + 0.32X_1' + 0.84X_4 + 8.51X_3 \qquad R^2 = 0.71 \quad d = 2.50$$
$$\qquad\qquad\qquad\quad (0.05) \qquad (0.25) \qquad (4.03)$$

[12] Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska and Kansas.

1924-1936, respectively; equations 7 and 8 are computed for fall farrowings in the North Central region for the same periods. The variables are defined as follows:

$\hat{Y}_1$ = Estimated number of fall farrowings, United States (in 1,000 litters). The fall farrowing period extends from June through November, year t.

$\hat{Y}_2$ = Same as $\hat{Y}_1$ except for North Central region.

X_1 = Number of spring farrowings, United States (in 1,000 litters), i.e., from December, year t-1 through May, year t.

X_1' = Same as X_1 except for North Central region.

X_2 = Production of oats, barley and grain sorghum (in 100 tons), United States, year t.

X_3 = Ratio of the average price of slaughter steers at Chicago (in dollars per cwt.) to the average of corn at Chicago (in dollars per bu.) during March, April, May and June, year t.

X_4 = Change in corn production (in 100 tons), United States, from year t-1 to year t.

Analysis indicated that the decision to farrow sows for the fall period is not influenced significantly by prices at breeding time (March, April, May and June). Many sows bred for spring farrowing are merely carried over and farrow again in the fall; hence, X_1 is included as an independent variable. Anticipated feed grain supplies (reflected by X_2 and X_4) and the competitive position of beef cattle (reflected by X_3) are other important factors influencing fall farrowings. The fall farrowing equations provide a less satisfactory statistical "fit" than the spring farrowing equations, as indicated by lower R^2 values and larger standard errors of the estimate.

Comparisons of Farrowing Elasticities Over Time

While the equations presented above may serve usefully in prediction, they were developed mainly to allow comparisons of supply elasticities between time periods. Table 1 summarizes the elasticities of supply response (evaluated at the means of all variables) computed from the preceding farrowing functions. The elasticities in Table 1 measure the percentage change in the number of sows farrowing spring and fall in response to a 1 per cent change in hog prices during the previous October, November and December.[13]

[13] The elasticity computations for spring farrowings are straightforward. However, the hog-corn ratio is not included directly in the fall farrowing equations. But fall farrowings depend on spring farrowings, which in turn, depend on the hog-corn ratio in the preceding fall. Thus, fall farrowings are expressed as a function of the hog-corn ratio in the previous fall by combining the spring and fall farrowing equations. As examples, the right-hand side of equation 1 is substituted for X_1 in equation 5; the right-hand side of equation 2 is substituted for X_1 in equation 6, etc. Elasticity computations then are applied to the resulting equations.

For spring farrowings in both the United States and North Central region the point estimates of Table 1 reveal higher elasticities of supply response in the 1938-1956 period than in the 1924-1937 period. However, no consistent directional shift is apparent in the fall farrowing functions. An important consideration is whether the spring farrowing response elasticities actually are different between time periods or whether the observed differences might easily have occurred by chance. Statistical tests

TABLE 1. ELASTICITIES OF SUPPLY RESPONSE COMPUTED FROM FARROWING EQUATIONS 1 THROUGH 8

Equation	Area	Time period	Farrowing period	Elasticity of supply response[a]	Standard error of elasticity of supply response
1	U.S.	1938–1956[b]	Spring	0.60	0.09
2	U.S.	1924–1937	Spring	0.50	0.05
3	N. C. region	1938–1956[b]	Spring	0.69	0.11
4	N. C. region	1924–1937	Spring	0.58	0.06
5	U.S.	1937–1956[c]	Fall	0.30	0.11
6	U.S.	1924–1936	Fall	0.28	0.10
7	N. C. region	1937–1956[c]	Fall	0.35	0.19
8	N. C. region	1924–1936	Fall	0.41	0.10

[a] Elasticity of supply response measured as the percentage change in number of sows farrowing per 1 per cent change in the average hog-corn price ratio in the previous October, November and December. Elasticities are evaluated at the mean values of all variables for each sub-time period. Use of the hog-corn price ratio removes the necessity of deflating hog prices. If non-deflated hog prices were used in computing the elasticities, the difference between the elasticities for the two time periods would reflect movement along a supply curve as well as a shift in the supply curve.

[b] Omitting years 1942, 1943 and 1944.

[c] Omitting years 1941, 1942, 1943 and 1944.

indicate that the observed shifts between time periods are not sufficiently large for significance at generally accepted probability levels. However, the logical bases for expecting such a shift and the consistency in results for the United States and North Central region provide somewhat greater confidence in the estimates than is indicated by statistical significance tests alone.

Several reasons for hypothesizing an increase in the elasticity of supply response for hogs were mentioned earlier. Technological change appears especially important in explaining shifts in "price responsiveness." When hog prices in the fall months are favorable, producers now possess the physical resources and managerial skills to easily increase spring farrowings. The increased elasticity of supply response also implies that, as hog prices fall, producers restrict hog production more than formerly. Perhaps the favorable postwar capital position of farmers has contributed toward

a greater willingness to shift, when hog prices fall, from hog production into higher risk enterprises such as cattle feeding. The importance of technology in supply response is indicated in comparing elasticities for the United States with those for the North Central region. Greater technological change in hog production probably has taken place in the North Central region than in the United States as a whole. As expected, the point estimates of supply response elasticities are higher for the North Central region for both spring and fall farrowings and for both time periods (Table 1).

Comparisons of Spring Farrowing Response Elasticities from a More Complex Expectational Model

The preceding analysis assumed that the price hog producers expect in year t is equal to the observed price in the fall of year t-1. An alternative hypothesis is that expected price is a weighted average of past prices. Equation 9 expresses spring farrowings in year t as a function of two price ratios expected at the time when spring pigs are sold (October, November and December). Y = spring farrowings, P_h = price of hogs, P_c = price of corn, P_b = price of beef cattle, t = year, u = random residual and the asterisk denotes "expected" prices. Expected prices are assumed to take the special form hypothesized by Nerlove[14] and are indicated in equations 10 and 11: That is, farmers revise their expected price (price ratios in this case) in proportion to the error made in predicting last year's price (price ratio). The coefficient of expectation (β) is assumed to be identical for both expected price ratios.[15] An algebraic transformation, similar to Nerlove's for one expected price, allows estimation by least-squares of

$$(9) \qquad Y_t = a_0 + a_1\left(\frac{P_h}{P_c}\right)^*_t + a_2\left(\frac{P_b}{P_h}\right)^*_t + u_t$$

$$(10) \qquad \left(\frac{P_h}{P_c}\right)^*_t - \left(\frac{P_h}{P_c}\right)^*_{t-1} = \beta\left[\left(\frac{P_h}{P_c}\right)_{t-1} - \left(\frac{P_h}{P_c}\right)^*_{t-1}\right]$$

$$(11) \qquad \left(\frac{P_b}{P_h}\right)^*_t - \left(\frac{P_b}{P_h}\right)^*_{t-1} = \beta\left[\left(\frac{P_b}{P_h}\right)_t - \left(\frac{P_b}{P_h}\right)^*_{t-1}\right]$$

[14] Nerlove, Marc, "Estimates of Elasticities of Supply of Selected Agricultural Commodities," *Journal of Farm Economics*, Vol. 38, May, 1956, pp. 496-509.

[15] If this assumption is not made, the solution becomes quite complex. See Nerlove, *ibid.*, p. 502. An additional limitation of the above model is that the hog price is included in both expected price ratios; thus, the expectations for each ratio are related. In a recent publication Nerlove suggests more complicated alternative methods where several expected prices are involved. See Nerlove, Marc, *Distributed Lags and Demand Analysis*, U. S. Department of Agriculture Handbook No. 141, June, 1958.

the coefficients in equation 12.[16] Estimates of a_o, a_1, a_2 and β are then derived algebraically. The elasticities of supply response from this model are

$$(12) \quad Y_t = a_0\beta + a_1\beta\left(\frac{P_h}{P_c}\right)_{t-1} + a_2\beta\left(\frac{P_b}{P_h}\right)_{t-1} + (1-\beta)Y_{t-1} + v_t$$

similar in magnitude to those presented earlier (compare Tables 1 and 2) and are consistent with the hypothesis of an increase in elasticity over time for spring farrowings. The coefficients of expectation (β) do not differ significantly from unity when tested at the 5 per cent level; when $\beta = 1.0$,

TABLE 2. ESTIMATES OF RELEVANT STATISTICS AND ELASTICITIES OF SUPPLY RESPONSE FROM THE EXPECTED PRICE MODEL

Derived estimates	United States		North Central region	
	1924–1937	1938–1956[a]	1924–1937	1938–1956[a]
a_0	−6,283	−4,979	−5,875	−4,919
a_1	324	382	289	370
a_2	876	−119	858	193
R^2	0.91	0.76	0.87	0.79
Elasticity of supply response[b]	0.46	0.65	0.53	0.73

[a] Omitting 1942, 1943 and 1944.
[b] Indicates response of spring farrowings, year t, to the hog price expected to prevail in October, November and December, year t.

expected price in year t is identical with observed price in year t-1. Thus, support is provided for the assumption of the cobweb theorem that producers base future output on current prices.[17]

Analysis of Marketing Weights

Within the hog supply process, the most important changes in price responsiveness over time probably hinge on decisions on the number of sows to farrow. However, some notion is also required of the responsiveness of marketing weights to price and other factors. Average marketing weights are to some extent jointly determined with influences prevailing within the slaughter period. Hence, simultaneous equations appear to be an appropriate technique for investigating their interrelationship. The following analysis is carried out only for the United States as a whole.

August 1 to February 1 represents the period during which most of the spring pig crop moves to slaughter. Equations 13 and 14 are supply and

[16] For details of this transformation see Dean, G. W. and Heady, E. O., *Supply Functions for Hogs*, Iowa Agr. Exp. Sta. Bul. (forthcoming), 1958.

[17] However, the cobweb theorem need not be inconsistent with expectation models. See Nerlove, Marc, "Adaptive Expectations and Cobweb Phenomena," *Quarterly Journal of Economics*, Vol. 73, May, 1958, pp. 227-240.

(13) $\hat{Q} = -0.11 + 0.08P + 1.00Z$: Supply

(14) $\hat{P} = 3.80 - 1.55Q + 1.62Y$: Demand

demand equations, respectively, for this six-month marketing period from 1938-1956.[18] Variables are expressed in logarithms and are defined as follows:

Q = Total liveweight of hogs slaughtered under Federal inspection, United States, August 1, year t, to February 1, year t+1 (in units of 10^8 lbs.).

P = Average price of hogs (in dollars per cwt.) received by farmers from August 1, year t, to February 1, year t+1, United States, divided by the Index of Prices Received by Farmers For Livestock and Livestock Products (1947-1949 = 100), United States during the same period.[19]

Z = Estimate of Q based on predetermined variables.

Y = Per capita disposable personal income (in dollars), average of last two quarters, year t, United States, divided by the Index of Consumer Prices (1947-1949 = 100), United States during the same period.

At the beginning of the marketing period an estimate (Z) can be made of hog slaughter based on variables determined in advance of the marketing period. The variables Z estimates the general level of hog slaughter (Q) expected during the marketing period. Deviations from this general level are caused primarily by changes in average marketing weights, which in turn are influenced by hog prices (P) within the marketing period. Since the variables are in logarithmic form, the coefficient of P (0.08) can be directly interpreted as the within-marketing-period elasticity of supply response. Because total hog slaughter is affected relatively little by changes in average marketing weights, this coefficient is, as expected, small in magnitude and positive.

Equations 15 and 16 represent supply and demand equations, respectively, for the same marketing period (August 1 to February 1), 1924-1937. As before, the signs of all coefficients are consistent with theory, and

(15) $\hat{Q} = -0.19 + 0.04P + 1.03Z$: Supply

(16) $\hat{P} = 1.36 - 0.63Q + 0.98Y$: Demand

again the elasticity of supply response (0.04) is positive but small.

A major portion of the fall pig crop is marketed during the six-month period from February 1 to August 1. Equations 17 and 18 are estimated for this six-month marketing period from 1938-1956. Variables once again

[18] The general model was used by Fox, Karl A., *op. cit.*, p. 31-32.

[19] Ideally, the hog price component would not have been included in the deflator.

(17) $\hat{Q} = 0.66 + 0.05P + 0.85Z$: Supply

(18) $\hat{P} = 4.52 - 1.61Q + 1.45Y$: Demand

are expressed in logarithms and are defined as previously except that they now pertain to the February 1 to August 1 period. Equations 19 and 20 are the estimated supply and demand equations, respectively, for the

(19) $\hat{Q} = -0.22 + 0.07P + 1.03Z$: Supply

(20) $\hat{P} = 0.55 - 0.36Q + 0.83Y$: Demand

February 1 to August 1 period, 1924-1937.

Elasticities of supply and demand from the simple preceding model are presented in Table 3. The individual elasticities of supply response are not estimated with sufficient precision statistically to allow a high degree of confidence in interpretation. However, it seems fairly safe to state that the within-marketing-period supply response is quite inelastic and has not changed appreciably over time.

TABLE 3. ELASTICITIES DERIVED FOR SIX-MONTH MARKETING PERIODS, UNITED STATES

Years	Six-month marketing period	Elasticity of supply response within marketing period	Price elasticity of demand	Income elasticity of demand
1938–1956[a]	Aug. 1–Feb. 1	0.08	−0.65	1.04
1924–1937	Aug. 1–Feb. 1	0.04	−1.59	1.56
1938–1956[a]	Feb. 1–Aug. 1	0.05	−0.62	0.90
1924–1937	Feb. 1–Aug. 1	0.07	−2.75	2.29

[a] Omitting 1942 through 1946.

The price elasticities of demand obtained from the above model and presented in Table 3 show a marked decrease from the 1924-1937 period to the 1938-1956 period. However, the demand elasticities for the 1924-1937 period appear unreasonably high, at least in comparison with previous estimates.[20] While the magnitude of the change in the price elasticity of demand from 1924-1937 to 1938- 1956 undoubtedly is overestimated by the simple two-equation models, the results are consistent with the earlier hypothesis of a decrease in the elasticity of demand over time.[21]

[20] For example, see Fox, *ibid.*, p. 43-46 and Learn, Elmer W., "Estimating Demand for Livestock Products at the Farm Level," *Journal of Farm Economics*, Vol. 38, December, 1956, pp. 1487-1488.

[21] A decrease in the elasticity of demand for pork also is suggested by graphic analyses presented by Waugh. See Waugh, F. V., *Graphic Analysis in Agricultural Economics*, U. S. Department of Agriculture Handbook No. 128, 1957, pp. 30-31. The method of analyses used by Waugh is an extension of work by Shepherd, *et al.* See Shepherd, G. S., Purcell, J. C. and Manderscheid, L. V., *Economic Analysis of Trends in Beef Cattle and Hog Prices*, Iowa Agr. Exp. Sta. Res. Bul. 405, 1954, p. 737.

The income elasticity of demand estimates presented in Table 3 also decrease over time, lending support to the proposition that pork has become more of a staple food in the diets of American families.

Implications for Outlook and Extension

The above empirical analysis provides support for the hypothesis of an increase over time in the supply elasticity for hogs, at least with regard to the number of spring farrowings in response to hog prices at breeding time. Under these circumstances, outlook information presented to farmers can serve a very useful function in reducing wide cyclical hog price fluctuations. The possible role of outlook information can be demonstrated by reference to diagram 1, Fig. 4. Assume quantity Q_1 and Price P_1 occur in time period 1. Normally, Q_2 will be supplied in period 2. However, if producers are made aware of the typical response to low prices, they will revise their individual price expectations upward and produce Q_2' rather than Q_2 in period 2. The revision in expectations is indicated by the upward curving line from P_1 to Q_2' i.e., a price P_1 calls forth a supply Q_2' rather than Q_2. Likewise, if producers are informed that when hog prices are relatively high excess supplies and low hog prices will result, they will revise their price expectations downward and produce less. For example, a price P_2' in period 2 (diagram 1) might call forth a supply Q_3' in period 3. The rapidly converging cyclical pattern resulting from such revised price expectations is contrasted with the more slowly converging conventional representation.

In effect, an informational program could cause a decrease in the elasticity of supply response as shown in diagram 2, Fig. 4. At price P_2 the usual response is OQ_2 represented at point A on the supply response function S_1S_1'. With additional outlook information, however, producers might

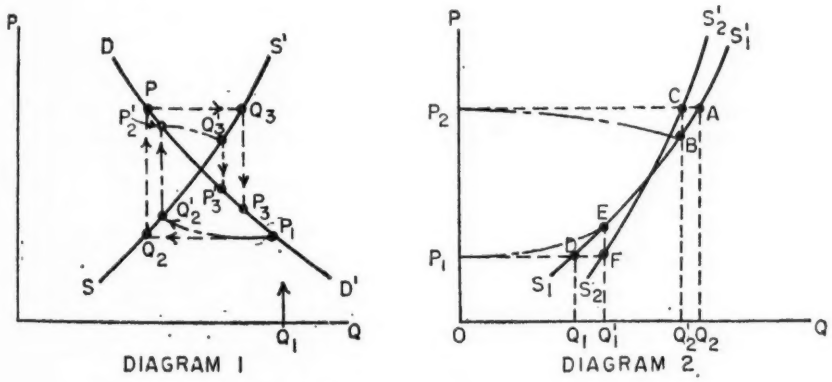

FIG. 4. CHANGES IN SUPPLY RESPONSE ACCOMPANYING AN OUTLOOK AND EDUCATIONAL PROGRAM

revise price expectations downward and produce only OQ_2'; this output can be represented as before, by a downward curving line to point B on the supply response function S_1S_1' or by a straight line (the conventional method) to point C on a new supply response function S_2S_2'. Conversely, at Point P_1 the usual response is OQ_1 represented by Point D on the "old" supply response function S_1S_1'. With adequate information producers might revise price expectations upward and produce OQ_1'; again this output can be represented by point E on supply response function S_1S_1' or by point F on the new supply response function S_2S_2'.

The above discussion emphasizes the potential value of intensified outlook and educational programs for hog farmers. Normally, if no significant time lag exists between production plans and output of a product, price fluctuations vary inversely in magnitude with supply elasticity. Under the cobweb relationship hypothesized for hogs, however, price fluctuations can be reduced by decreasing the elasticity of supply response with respect to the most recent price. Hog price instability might also be reduced if farmers respond to "expected" price (e.g., a weighted average of past prices as suggested by Nerlove) rather than most recent price alone. At a time when the demand for pork apparently is becoming more inelastic, an adjustment in supply response appears doubly important.

STATISTICAL ESTIMATION OF LONG-RUN ELASTICITIES OF SUPPLY AND DEMAND

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RECENT hearings of the Subcommittee on Agriculture Policy of the Joint Economic Committee have re-emphasized the need for knowledge of the long-run elasticities of the supply and demand for individual agricultural commodities.[1] In a discussion of the role of the price mechanism in bringing about long-term adjustments and growth, the authors are not so much concerned with the short-term fluctuations and problems of instability which have received the major attention of agricultural economists in recent years. Formulation of an appropriate agricultural price policy for growth and stability requires an understanding of the long-run effects of price changes upon producers and consumers as well as the short-run effects.

In an earlier paper, to which the present paper is a sequel, one of the authors of this paper attempted to demonstrate that statistical estimation of long-run elasticities of supply or demand is possible and, indeed, logically prior to estimation of short-run elasticities.[2] The real world presents us with a curious mixture of short- and long-run adjustments. In order to disentangle the two, it is necessary to investigate the underlying long-run adjustments upon which short-run adjustments are superimposed. Thus, from the point of view of both agricultural policy and econometric technique, investigation of long-run elasticities is necessary and desirable. The illustrative statistical results presented here show, it is hoped, that our optimism regarding the possibility of estimating long-run elasticities is not misconceived.[3]

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* On military leave.

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[1] *Policy for Commercial Agriculture, Its Relation to Economic Growth and Stability,* papers submitted by panelists appearing before the Subcommittee on Agricultural Policy of the Joint Economic Committee (Washington: United States Government Printing Office, 1957). See especially: M. R. Benedict, "Current Imbalance of Supply and Demand for Farm Products," pp. 91-107; Rex F. Daly, "Prospective Demands for Food and Fiber," p. 108-118; Karl A. Fox, "Effects of Farm Product Prices on Production and Commercial Sales," pp. 405-429; and E. J. Working, "How Effective Are Prices and Incomes in Bringing About Adjustments within Agriculture?", pp. 430-436.

[2] Nerlove, Marc, "Distributed Lags and the Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations," *Journal of Farm Economics,* Vol. 40, May 1958, pp. 301-311.

[3] The term long-run is used here in the sense in which Marshall used the term long-period "normal"; see Alfred Marshall, *Principles of Economics,* eighth edition (London: Macmillan, 1936), pp. 378-379. The notion should be distinguished from

Previous contributions. In a paper of this length it is impossible to do justice to one's intellectual predecessors; nevertheless, the contributions of John M. Cassels and several others must at least be mentioned.

In an article published in 1933, Cassels distinguished between "market," "short-run normal," and "long-run normal" supply curves.[4] Statistical investigation of "market" supply curves (i.e., curves referring to the shortest of all short runs when the stock of the commodity in question is fixed) were doomed, he felt, to failure at the start. Statistical derivation of "long-run normal" supply curves was also likely to prove difficult, inasmuch as it would be impossible to hold determining factors constant long enough to observe long-run equilibrium. Cassels was hardly more sanguine about the possibility of estimating the short-run elasticity. He recognized that there is more than one short-run supply relationship:

> "The more sudden and violent the increase in demand the more difficult it will be for supply to keep pace with it. Time is required for the organization of extra shifts, for the renovation of old machinery, for the augmentation of the labor force and for the assembling of additional supplies of the input elements. More time is required for new producers to come into the field and still more for efficiency to be introduced into all the new arrangements. The longer the period allowed for adjustments to be made, the more successfully can the tendency to transitional decreasing returns be overcome and the more advantage can be taken of the economies of the large-scale production. . . [Hence], there is no curve which can be regarded as the *one-and-only* supply curve for any particular commodity."[5]

Cassels concluded ". . . although it may be reasonable to assume that each price observation corresponds to a point on *the* demand curve we cannot say that it represents a point on *the* supply curve."[5,6] He went on to point out the possibility of irreversibilities in the short-run supply curve; he suggested ". . . that each supply curve must be regarded as relating to an established level of output and should be recognized to have two distinct parts, one representing expansion beyond that output and the

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the concept of "secular" change which refers to gradual changes over time caused by changes in the state of the arts, population, tastes, etc. Secular change becomes of special importance when long-range forecasts are attempted. Where the authors believe such changes are important, a trend variable is generally introduced to take account of them, but beyond such a simple expedient this paper does not venture.

It should also be noted that the terms "static" and "dynamic" are used in a sense different from common usage.

[4] Cassels, John M., "The Nature of Statistical Supply Curves," *Journal of Farm Economics*, Vol. 15 (April 1933), pp. 378-387.

[5] *Ibid.*, p. 382.

[6] Cassels thus makes the same point with reference to supply that was made in the paper cited in footnote 2 with reference to both supply and demand. If he had carried his analysis further and spelled out what happens when the short-run elasticities of supply differ from the long-run, he might have obtained a solution to the problem he posed.

other representing contraction below it."[7] Until now, there has been little concentrated effort to deal directly with the problem Cassels posed on the supply side.[8]

Following Cassels, Mighell and Allen recognized the importance of long-run demand,[9] but it remained for Elmer Working to make the first serious attempt to measure the difference between short-run and long-run elasticities of demand.[10] In his study of the demand for meat in the United States, Working distinguishes between short- and long-run elasticities of demand with respect to both price and income. His approach consists essentially in examining moving averages of quantity and income in relation to current price. The difficulty involved in the interpretation of Working's results has been demonstrated in recent discussion in this *Journal*.[11] While this approach has several points of similarity with Working's this is both simpler and more susceptible of direct interpretation in terms of long-run elasticities.[12]

Resumé of the method employed. Because the methods employed in this paper have been discussed elsewhere,[13] we shall only outline them here.

Consider first a long-run demand function such as

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[7] Cassels, p. 384. This amounts, in the terminology used below, to the assumption that the coefficient or elasticity of adjustment differs depending on whether output is being exapnded or contracted. In an investigation designed to test this hypothesis, evidence has been found which suggests the difference, if any, is slight.

[8] Black's earlier work on production economics (e.g., *Introduction to Production Economics*, 1926) suggests another, more indirect approach to supply. In their article, "Supply Schedules—'Long-Time' and 'Short-Time,'" *Journal of Farm Economics*, Vol. 22 (August 1940), pp. 544-557, R. L. Mighell and R. H. Allen brought Black's approach together with Cassels' criticism of time-series analysis of supply response. While Black's approach has contributed greatly to farm management analysis, it has not been nearly so useful in understanding farmers' aggregate response to price.

[9] Mighell, R. L., and R. H. Allen, "Demand Schedules—'Normal' and 'Instantaneous,'" *Journal of Farm Economics*, Vol. 21 (August 1939), pp. 555-569. For example they state (p. 555): "We have not developed a satisfactory explanation of normal or long-time demand. Nothing that has been done on the subject has given us an adequate approach to the problem of consumers' response to price over more than the short-term. We have developed neither the theory nor the methodology for estimating what quantity will presently be taken by consumers if the price has definitely fallen to a level 10 per cent lower relative to other prices. . . ."

[10] Working, Elmer J., *Demand for Meat* (Chicago: Institute of Meat Packing, 1954).

[11] Kuznets, G. M., "Measurement of Market Demand with Particular Reference to Consumer Demand for Food," *Journal of Farm Economics*, Vol. 35 (December 1953), p. 887; William G. O'Regan, "Demand for Meat," *Journal of Farm Economics*, Vol. 37 (November 1955), pp. 752-755; and Conrad Gislason, "A Note on Long-Run Price Elasticity," *Journal of Farm Economics*, Vol. 39 (August 1957), pp. 798-802.

[12] See the graphical derivation of the estimating equations used here in the reference cited in footnote 2.

[13] The simpler aspects of the problem and the method have been discussed graphically in the reference cited in footnote 2. The more complicated extensions of the method and several special problems are discussed more mathematically in Marc

$$\bar{q}_t = a + bp_t + cy_t, \tag{1}$$

where $\bar{q}_t$ represents the long-run equilibrium quantity demanded or its logarithm, p_t is current price or its logarithm, and y_t is current income or its logarithm. To take account of changes in population and the general price level, we shall take both quantity and income in per capita terms and deflate both price and income by an index of the general price level for all consumption goods. The long-run equilibrium quantity demanded, $\bar{q}_t$, is not observable, so equation (1) cannot be estimated directly. On the basis of considerations presented in the earlier paper, we suppose the relation between the observed quantity and the equilibrium quantity demanded at time t, q_t and $\bar{q}_t$ respectively, to be given by the following difference equation

$$q_t - q_{t-1} = \gamma[\bar{q}_t - q_{t-1}], \tag{2}$$

where γ is called the elasticity or coefficient of adjustment according to whether q_t and $\bar{q}_t$ are expressed in logarithms or not. Substitution of equation (1) into equation (2) yields an equation which can be estimated statistically

$$q_t = a\gamma + b\gamma p_t + c\gamma y_t + (1 - \gamma)q_{t-1} + u_t, \tag{3}$$

where u_t is a randomly distributed residual term added to show that the relation need not hold exactly. The coefficients of the long-run demand function (1), may be derived from estimates of the coefficients of price, income, and lagged quantity in (3); hence, long-run elasticities may also be derived. The elasticity or coefficient of adjustment, γ, determines the relation among the short-run elasticities and the long-run elasticity and can be obtained by subtracting the statistically determined coefficient of q_{t-1} in (3) from one. By dividing the coefficients of price and income by our estimate of γ we obtain price and income elasticities (or slopes) of the long-run demand function.[14]

The method for deriving statistical estimates of long-run supply elasticities is similar to the method described in the preceding paragraph. The traditional approach to supply for individual agricultural commodities involves the use of planted or harvested acreage to represent planned output. Despite certain difficulties entailed in such an approach,[15] we

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Nerlove, *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*, Agriculture Handbook No. 141, Agricultural Marketing Service, United States Department of Agriculture, 1958.

[14] The method can be easily extended to cover cases in which the prices of substitute or complementary commodities are included in the long-run demand function; see the second reference cited in footnote 13.

[15] See Chapter III, "Application to Agricultural Commodities," of Marc Nerlove, *The Dynamics of Supply: Estimation of Farmers' Response to Price* (Baltimore: The Johns Hopkins Press, 1958), in press.

shall follow it here. Let x_t be the current acreage devoted to a particular crop, and let $\bar{x}_t$ be the long-run equilibrium acreage that would be used for the production of a given crop if price and other factors were to remain constant for a sufficiently long period of time. On the assumption that farmers base their decisions on price lagged one year,[16] the long-run supply function may be written

$$\bar{x}_t = a + bp_{t-1} + ct, \tag{4}$$

where p_{t-1} is the price of the commodity lagged one year, and t is a trend variable representing changes in those factors which cannot conveniently be incorporated directly into the analysis. To take account of the prices of agricultural commodities which may compete in production with the crop in question, we shall deflate p_{t-1} by an index of prices received by farmers for all commodities in period $t-1$. The supply adjustment equation corresponding to (2) above is

$$x_t - x_{t-1} = \gamma[\bar{x}_t - x_{t-1}], \tag{5}$$

where x_t is current acreage. Substitution of (5) in (4) yields our estimating equation

$$x_t = a\gamma + b\gamma p_{t-1} + c\gamma t + (1 - \gamma)x_{t-1} + u_t. \tag{6}$$

The long-run elasticity of supply may be derived from estimates of the coefficients of p_{t-1} and x_{t-1} in (6) in exactly the same ways as in the case of demand.[17]

Both supply and demand analyses have been conducted using the methods outlined above. Because this paper explores the methodology of estimating long-run elasticities, poor as well as good results are presented. In the following two sections the main statistical results are presented. In those few cases in which the analysis did not turn out well, tentative explanations are offered. The most striking finding is that evi-

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[16] While this approach may appear to differ significantly from the "expected price" approach taken earlier by one of the authors (see the reference cited in footnote 15 and Marc Nerlove, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *Journal of Farm Economics*, Vol. 38 (May 1956), pp. 496-509), it is less different than one might at first suppose. As indicated in the reference cited in footnote 2, the present approach takes account of nonstatic expectations implicitly, while the "expected price" approach takes account of them explicitly. For an application of methods which take nonstatic expectations explicitly into account see Marc Nerlove, "The Implications of Friedman's Permanent Income Hypothesis for Demand Analysis," *Agricultural Economics Research*, Vol. 10 (January 1958), pp. 1-14.

[17] Of course, if, as in the case below, acreage and price are not expressed as logarithms, it is necessary to obtain an estimate of the elasticity by multiplying the estimate of the slope of the long-run supply function, b, by the ratio of price to acreage at some point. The authors always take this point to be average price and average acreage for the period of the analysis.

dence of serial correlation in the calculated residuals of analyses based on the dynamic models proposed above is nil compared with the evidence of it in the residuals of other types of analyses. The implications of this finding are explored in a separate section below.

Statistical Demand Analyses

The demand for various items of consumption in the United Kingdom, 1920 to 1938, was chosen for testing our method of estimating long run elasticities of demand. There are two reasons for this choice:

Data on a large number of consumption items were already at hand; no great labor was involved in selecting the series to be used and performing the various adjustments of the data which are almost always necessary in any statistical analysis. Twelve separate commodity groups were considered: (1) Bread and Cereals; (2) Meat, Poultry, and Eggs; (3) Fish; (4) Dairy Products; (5) Margarine and Other Fats; (6) Vegetables; (7) Fruit and Nuts; (8) Sugar, Chocolate, and Confectionery; (9) Tea, Coffee, and Cocoa; (10) All Other Foods not included above; (11) Alcoholic Drinks; and (12) Tobacco. For good measure, the over-all aggregate of (1)-(10), consumption of all foods, was also considered. Price and quantity indices for these groups of commodities, 1920-1938, have been constructed by Stone.[18] Prest's figures on the national income of the United Kingdom are readily available,[19] and population figures, used to put quantities and income on a per capita basis are available, from Stone.[20]

[18] Stone, Richard, *The Measurement of Consumers' Expenditure and Behavior in the United Kingdom, 1920-38*, Vol. I (Cambridge: Cambridge University Press, 1954). Page and table references for the series used are as follows: (1) Bread and Cereals: Table 5, p. 28; (2) Meat, Poultry, and Eggs: Table 13, p. 53; (3) Fish: Table 19, p. 68; (4) Dairy Products: Table 30, p. 96; (5) Margarine and Other Fats: Table 34, p. 103; (6) Vegetables: Table 39, p. 121; (7) Fruit and Nuts: Table 43, p. 136; (8) Sugar, Chocolate, and Confectionery: Table 48, p. 144; (9) Tea, Coffee and Cocoa: Table 52, p. 151; (10) Other Foods (including jam and marmalade, honey, syrup and treacle, soft drinks, fish and chips, ice cream, vinegar, pickles and sauces, and other miscellaneous prepared foods): Table 56, p. 161; (11) All Foods: Table 66, p. 174; (12) Alcoholic Drinks: Table 74, p. 190; (13) Tobacco: Table 81, p. 195. Stone's indices possess a helpful property: The price and quantity indices for commodity groups (1)-(10) sum to the corresponding indices for group (11), All Foods. This property is useful for examining the sensitivity of elasticities of adjustment to aggregation bias; however, the results of the authors' investigation of this aspect of the problem are not presented here.

[19] Prest, A. R., "National Income of the United Kingdom, 1870-1946," *Economic Journal*, Vol. 58 (1948), pp. 31-62.

[20] Reference cited in footnote 18, Table 116, p. 414. Because Stone's estimate of the number of equivalent adults (Table 117, p. 417) is tied to his estimation of income elasticities from cross-section data, not the equivalent adult but the total population series is used here. In the cases of alcoholic drinks and tobacco, however, population age 14 and over was used (readily obtained from Table 116, p. 414). Some of the difficulties involved in estimating income elasticities from cross-section data when dynamic elements are present are discussed briefly in the final reference

An index of all prices paid by consumers, used to deflate the prices of individual commodities and income, was also readily available.[21]

The second reason for investigating the demand for various foodstuffs, alcoholic drinks, and tobacco in the United Kingdom is of a more technical nature: Equation (3), our estimating equation for long-run demand analyses, can be estimated properly by least squares only under the assumption that supply is perfectly elastic. In the United States it is quite clear that the assumption of perfectly elastic supply is untenable for the majority of agricultural commodities. On the other hand, the prices of the majority of the commodities considered for the U. K. are closely tied to the world market. Of course, the strength of this connection varies. In the case of Bread and Cereals, for example, more than 80 per cent of the wheat is imported, but approximately 90 per cent of the total supply of flour is milled in the U. K., and the various products made from flour are almost entirely domestically produced. Unless, therefore, there was substantial overcapacity in the milling and baking industries, throughout the period of analysis, 1921-38, the assumption of perfectly elastic supply is only an approximation. Again, about half of the beef, 40 per cent of the lamb and mutton, 85 per cent of the pork, and significant proportions of the poultry and egg consumption in the U. K. were domestically produced in the interwar period. At best the assumption of perfectly elastic supply is an approximation, but it is a far better approximation than it would be for the United States. The method employed may be extended to situations in which supply is less than perfectly elastic. This extension is discussed in section 4 below. The case in which supply is perfectly inelastic may be of some interest.[22]

By taking reasonably comprehensive commodity groups, we hoped that whatever substitution took place would occur within the commodity group and not between commodity groups. Thus, a simple analysis, based on an equation such as (3), might be expected to work reasonably well. In most cases, the commodity groups chosen were sufficiently large;

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cited in footnote 16. These difficulties could conceivably lead to bias in the estimation of appropriate equivalent-adult scales: the adjustment of the data by the scale could partly take account of the effects of dynamic elements rather than wholly reflect the effects of age and sex in the family units under consideration.

[21] Reference cited in footnote 19. Stone deflated the price of each commodity by an index excluding the price of that commodity. While this procedure would have been preferable, Stone's deflating indices were not readily available.

[22] According to Fox, the assumption of perfectly inelastic supply conditions is appropriate when estimating the demands for many agricultural products in the United States. See Karl A. Fox, "Structural Analysis and the Measurement of Demand for Farm Products," *Review of Economics and Statistics*, Vol. 36 (1954), pp. 57-66. The existence of several outlets for many agricultural commodities and marketing and processing sectors, however, tends to cast some doubt on Fox's proposition.

however, in the case of margarine and other fats, the strong substitute butter was included in another commodity group, dairy products, and the analysis for Margarine and Other Fats was poor. As indicated in a footnote above, the method may easily be extended to cases in which the prices of competing or complementary commodities are included in the demand equation, but such examples are not included here.

Results from regressions based on equation (3) are presented in Table 1. For each commodity group the following is given: (a) the estimated elasticity of adjustment; (b) the estimated short- and long-run elasticities of demand with respect to price and income;[23] (c) the square of the coefficient of multiple correlation; and (d) the Durbin-Watson statistic used to test for serial correlation in the calculated residuals.[24] Results based on a more traditional static approach (one which does not distinguish between short- and long-run elasticities) are presented in Table 2. These analyses are from regressions of quantity on price and income (quantity and income in per capita and price and income in real terms), and are useful for comparative purposes. For each commodity group the following is given: (a) the estimated price and income elasticities of demand; (b) the square of the coefficient of multiple correlation; and (c) the Durbin-Watson statistic.

Table 1 shows that the elasticities of adjustment range between 0.15 for Other Foods to 1.00 for Fish. Alcoholic Drinks, Sugar, Chocolate, and Confectionery, Fish, and Bread and Cereals are those commodity groups with large elasticities of adjustment, i.e., relatively swift adjust-

[23] For convenience the expression short-run elasticity is used to refer to the elasticity over one observation period, in this case one year. It should be recognized that this is a loose form of expression, for, strictly speaking, there is no unique short-run elasticity of supply or demand with respect to price or any other variable: the elasticity differs depending on the length of time we allow for adjustment.

The reader should also note that the tests of significance apply only to the short-run elasticities and not the long-run as well. This is because the long-run elasticity depends on the ratio of two coefficients in the basic regression. Although a test of significance could have been devised for the long-run elasticities, this was not done.

[24] For an explanation of this statistic, its uses and limitations, see J. Durbin and G. S. Watson, "Testing for Serial Correlation in Least Squares Regression, II," *Biometrika*, Vol. 38 (1951), pp. 159-178. If no serial correlation is present, the statistic tends to be about two. Positive serial correlation tends to make the statistic less than two, and negative serial correlation, greater than two. For a given level of significance, Durbin and Watson are able to set upper and lower limits to the critical value of the statistic, below which significant positive serial correlation would be indicated or above which significant negative serial correlation would be indicated. In the test for, say, positive serial correlation, a value of the statistic above the upper limit indicates insignificant positive serial correlation, while a value below the lower limit indicates significant positive serial correlation. A value falling between the two limits is inconclusive. Durbin and Watson give procedures for determining the significance or lack of significance of serial correlation in such cases, but the procedures are quite complicated computationally. Inconclusive results have not been further explored in view of the labor involved.

TABLE 1. SELECTED STATISTICAL RESULTS: DYNAMIC DEMAND ANALYSIS, U. K., 1921–38

Commodity group	Elasticity of adjustment	Short-run elasticity re:		Long-run elasticity re:		R^2	Durbin-Watson statistic
		Price	Income	Price	Income		
1. Bread and Cereals	0.79	−0.37	0.36	−.47	0.46	0.93	2.35
2. Meat, Poultry, and Eggs	.41	−.24	.05	−.59	.12	.90	2.05
3. Fish	1.00[a]	−.15	.05	−.15	.05	.03	1.54
4. Dairy Products	.32	−.32	.09	−1.00	.28	.95	2.17
5. Margarine and Other Fats	.28	.21[b]	.05	—	.18	.82	1.65
6. Vegetables	.36	.06[b]	.13	—	.36	.71	2.35
7. Fruits and Nuts	.33	−.75	−.25[b]	−2.27	−.76	.80	1.86
8. Sugar, Chocolate, and Confectionery	.95	−.43	.30	−.45	.33	.98	2.38
9. Tea, Coffee, and Cocoa	.35	−.15	.02	−.43	.06	.74	1.30[c]
10. Other Foods	.15	−.51	.01	−3.33	.07	.99	2.22
11. All Foods	.29	−.24	.04	−.83	.14	.99	1.67
12. Alcoholic Drinks	.89	−1.02	−.25[b]	−1.15	−.28	.97	1.59
13. Tobacco	.19	−.08	.55	−.42	2.90	.99	1.54

[a] Insignificantly different from one at the .05 level.
[b] Insignificantly different from zero at the .05 level.
[c] Inconclusive test for serial correlation in the residuals.
Note: Significance tests apply only to the short-run elasticities. See footnote 23.

ment of the current quantity consumed to the long-run equilibrium quantity. The differences among the short-run elasticities and the long-run elasticities are correspondingly slight. Tobacco and Other Foods have rather low elasticities of adjustment, indicative of a slow adjustment of current to long-run equilibrium quantity. The differences, consequently, among the short-run elasticities and the long-run elasticity are quite marked for these two commodity groups. Eight out of the 13 R^2's are greater than 0.9 and all are large with the exception of Fish which is close to zero. All commodity groups have negative price elasticities with the exception of Margarine and Other Fats and Vegetables; and all have positive income elasticities except Fruit and Nuts and Alcoholic Drinks.

Although the negative income elasticities for Alcoholic Drinks and Fruit and Nuts are rather surprising, they are not significantly different from zero. An explanation for the negative income elasticity of demand for Alcoholic Drinks may lie in the fact that the quantity index is based on liquid volume figures. The quality difference between, say, equal volumes of beer and cognac is great; since people with higher incomes tend to consume higher quality beverages and correspondingly less volume, the negative relation between volume and income is not unreasonable. We have no explanation for the Fruit and Nuts result. In view of the breadth of items included in each commodity group and the simplicity of the analytical framework employed, the analyses turned out

TABLE 2. SELECTED STATISTICAL RESULTS: STATIC DEMAND ANALYSES, U. K., 1921–38

Commodity group	Price elasticity	Income elasticity	R^2	Durbin-Watson statistic
1. Bread and Cereals	−.41	0.45	0.92	1.95
2. Meat, Poultry, and Eggs	−.50	.35	.76	.56[c]
3. Fish	−.15	.05	.03	1.55
4. Dairy Products	−.70	.74	.91	1.56
5. Margarine and Other Fats	0.50[a]	−.66	.71	1.34[d]
6. Vegetables	0.08[b]	.44	.52	1.47
7. Fruit and Nuts	−.49	.67	.55	.44[c]
8. Sugar, Chocolate, and Confectionery	−.45	.33	.98	2.26
9. Tea, Coffee, and Cocoa	−.30	.15	.48	.66[c]
10. Other Foods	−.95	.63	.91	.70[c]
11. All Foods	−.84	.31	.92	.46[c]
12. Alcoholic Drinks	−1.12	−.36	.97	1.79
13. Tobacco	−.15	1.29	.78	.75[c]

[a] Statistically significant at the .05 level.
[b] Insignificantly different from zero at the .05 level.
[c] Significant positive serial correlation in the residuals.
[d] Inconclusive test for serial correlation in the residuals.

well. The exceptions are Fish, Margarine and Other Fats, and Vegetables. While Stone has accomplished a nearly impossible task in assembling the basic data on food consumption in the United Kingdom, it should be recognized that he had neither the resources available to a large Government agency nor statistics comparable to those available in the United States for some commodities. Some of these poor results may be due to faulty data as well as to aggregation. However, the authors have not explored the data in sufficient detail to see whether deficiencies in them could account for those analyses which turned out badly.[25]

Comparison of the results of the dynamic analyses presented in Table 1 with those of the static analyses presented in Table 2 reveals that the multiple correlations in several cases are markedly lower for the static analyses. More important, however, is the comparison between the two sets of Durbin-Watson statistics. In the static analyses there are six cases of significant positive serial correlation in the residuals calculated from the regression. In one case an inconclusive test is obtained, but the evidence of serial correlation is very close to being significant. Contrast these findings with those obtained for the dynamic analyses presented in Table 1: No significant positive serial correlation is found in the calculated residuals.

[25] James P. Cavin has examined Stone's vegetable series in some detail and reports several serious shortcomings. The authors have examined Stone's fish series and find that the fish consumed in "fish and chips" are not included in his index. Since "fish and chips" are a significant feature of the British diet, the poor result for Fish may perhaps be due to the limitations of the data. In the case of Margarine and Other Fats, the price of an important substitute, butter, has been omitted. This omission may account for the poor results in connection with the Margarine and Other Fats group.

One inconclusive test is obtained to be sure, but, overall, the contrast with Table 2 is striking. This remarkable absence of serial correlation in the residuals when this method is employed is repeated for the supply analyses presented below, and there are further comments on it in a subsequent section. Another finding worthy of comment is the rather small elasticity of adjustment for the aggregate All Foods as compared with the elasticities of adjustment for the component commodity groups. This may be an effect of aggregation in estimating elasticities or coefficients of adjustment for large groups of commodities.[26]

Statistical Supply Analyses

The statistical supply analyses presented here for twenty vegetables produced for fresh market in the United States, form part of a more extensive project on the measurement of supply response being carried on in the Agricultural Marketing Service.[27] They are preliminary analyses and presented mainly for illustrative purposes. Although they are very good on the whole we do not regard them as final.

Statistical regressions based on equation (6), above, have been obtained for twenty vegetable crops. The major crops include: (1) Lima Beans, (2) Snap Beans, (3) Cabbage, (4) Carrots, (5) Cucumbers, (6) Lettuce, (7) Onions, (8) Green Peas, (9) Green Peppers, (10) Tomatoes, and (11) Watermelons. The minor crops include (12) Artichokes (acreage and price data for California only) (13) Beets, (14) Cantaloupes, (15) Cauliflower, (16) Celery, (17) Eggplant, (18) Kale (acreage and price data for Virginia only), (19) Spinach, and (20) Shallots (acreage and price data for Louisiana only). In addition to lagged price and lagged acreage, linear trend is included in these analyses. Both acreage and price data are from published Agricultural Marketing Service sources and include the most up-to-date revisions. The length of the series used for the various analyses varies from crop to crop. All series have the same terminal year, 1955, but the series begin at different years during the period 1919 to 1929. The number of observations on which each regression was based, therefore,

[26] It may be of some interest to note that calculations for the aggregate of food consumption in the U. S. have been carried out by the methods outlined in this paper. For the period 1920-41 and 1948-55, a long-run price elasticity of —.19, a long-run income elasticity of 0.29, an elasticity of adjustment of 0.76, and an R^2 of 0.97 were obtained. Because of the high R^2, the bias resulting from the inappropriate assumption of perfect supply elasticity is likely to be slight. The higher elasticity of adjustment for the U. S. data than for the U. K. data is more reasonable. For further details on the results for the U. S., see the final reference cited in footnote 16.

[27] A full presentation, in less technical form, of the basic data, methodology, and results of this section will appear in a USDA Technical Bulletin scheduled for publication in 1959. Those of the results presented here are used primarily to support the methodological conclusions presented in section 5.

TABLE 3. SELECTED STATISTICAL RESULTS: DYNAMIC SUPPLY ANALYSES, VEGETABLES PRODUCED FOR FRESH MARKET IN THE U. S., SELECTED PERIODS, 1919–55

Crop	Coefficient of adjustment	Trend coefficient as a percentage of average acreage for the period of analysis	Short-run price elasticity	Long-run price elasticity	R^2	Durbin-Watson statistic
Major vegetables						
1. Green Lima Beans	0.06	−.3	0.10	1.7	0.90	2.01
2. Green Snap Beans	.00[a]	−.2	.15	∞[b]	.97	2.30
3. Cabbage	.29	.1	.36	1.2	.83	2.02
4. Carrots	.14	.4	.14	1.0	.95	1.90
5. Cucumbers	.13	.1	.29	2.2	.88	1.78
6. Lettuce	.19	.5	.03	.16	.94	2.25
7. Onions	.33	.7	.34	1.0	.75	2.41
8. Green Peas	.07	−.2	.31	4.4	.94	1.92
9. Green Peppers	.28	1.4	.07	.26	.96	1.85
10. Tomatoes	.18	.3	.16	.90	.94	1.94
11. Watermelons	.47	1.1	.23	.48	.90	1.49[c]
Minor vegetables						
12. Artichokes (Calif. only)	0.26	−0.0	−0.04[a]	−0.14[a]	0.63	1.44[c]
13. Beets	.13	−.7	.13	1.0	.87	2.56
14. Cantaloups	.51	.7	.02	.04	.73	1.68
15. Cauliflower	.13	.3	.14	1.1	.92	2.09
16. Celery	.15	.0	.14	.95	.94	1.90
17. Eggplant	.47	.0	.16	.34	.72	2.27
18. Kale (Va. only)	.87	2.0	.20	.23	.57	1.92
19. Spinach	.04	−.4	.20	4.7	.93	2.48[d]
20. Shallots (La. only)	.40	1.2	.12	.31	.53	2.09

[a] Coefficient from which derived is not significantly different from zero at the .05 level.
[b] Infinitely elastic long-run supply probably occurs only over a finite range of output. At very large outputs, snap beans are undoubtedly in less than infinitely elastic supply.
[c] Inconclusive test for positive serial correlation in the residuals.
[d] Inconclusive test for negative serial correlation in the residuals.
Note: Significance tests apply only to the short-run elasticities. See footnote 23.

varies between 27 and 37. The war years, 1941-46, are included in all analyses.[28]

Table 3 presents selected statistical results for the dynamic supply analyses. For each vegetable the following is given: (a) the estimated coefficient of adjustment;[29] (b) the estimated coefficient of trend in the multi-

[28] Data for price and acreage series for all vegetable crops discussed were taken from the following sources. (1) For the period 1918-1937, *Agricultural Statistics*, 1952; (2) 1938-1948, *Commercial Vegetables for Fresh Market*, Statistical Bulletin No. 126, May 1953; (3) 1948-1955, *Vegetables for Fresh Market*, Statistical Bulletin No. 212, June 1957. All are publications of the Agricultural Marketing Service (Washington: United States Government Printing Office). All values in the price series were converted to a hundredweight basis for comparability and deflated by the prices received index for all commodities as reported in *Agricultural Prices*, October 1956. Acres harvested for a particular crop were used for the acreage variable because data for planted acres are inadequate for the period considered.

[29] Inasmuch as all supply analyses were carried out with data in their original forms (i.e., not in logarithms as was the case for our demand analyses), reference here is to a *coefficient* rather than an *elasticity* of adjustment.

TABLE 4. SELECTED STATISTICAL RESULTS: STATIC SUPPLY ANALYSES, VEGETABLES PRODUCED FOR FRESH MARKET IN THE U. S., SELECTED PERIODS, 1919–55

Crop	Trend coefficient as a percentage of average acreage for the period of analysis	Price elasticity	R^2	Durbin-Watson statistic
Major vegetables				
1. Green Lima Beans	3.6	0.40	0.42	0.36[b]
2. Green Snap Beans	3.3	.21	.69	.14[b]
3. Cabbage	1.0	.35	.51	.41[b]
4. Carrots	4.6	.14	.84	.36[b]
5. Cucumbers	1.3	−.15[a]	.40	.53[b]
6. Lettuce	3.2	.21	.83	.37[b]
7. Onions	1.2	.24	.52	.70[b]
8. Green Peas	1.6	1.39	.43	.26[b]
9. Green Peppers	4.4	.01	.93	.61[b]
10. Tomatoes	2.5	.23	.83	.35[b]
11. Watermelons	2.6	.12	.86	1.01[b]
Minor vegetables				
12. Artichokes (Calif. only)	−.7	−.20[a]	0.21	0.51[b]
13. Beets	.2	.54	.33	.24[b]
14. Cantaloups	1.4	−.01[a]	.63	1.02[b]
15. Cauliflower	2.6	.19	.63	.26[b]
16. Celery	1.7	.40	.72	.54[b]
17. Eggplant	2.4	.16	.61	.92[b]
18. Kale (Va. only)	2.3	.21	.56	1.65
19. Spinach	1.9	.61	.31	.21[b]
20. Shallots (La. only)	1.7	.05	.29	1.04[b]

[a] Coefficient from which derived is not significantly different from zero at the .05 level.
[b] Significant positive serial correlation at the .05 level.

le regression divided by average acreage for the period of the analysis; c) the estimated price elasticity over one production period (short-run lasticity)[30] and the estimated long-run price elasticity of supply, both aken at mean price and acreage for the period of analysis; (d) the square f the coefficient of multiple correlation; and (e) the Durbin-Watson tatistic.

Results from analyses based on a static approach are presented in Table 4. These analyses are based on regressions of current acreage on agged deflated price and linear trend, and are useful for comparative urposes. For each vegetable the following is presented: (a) the estiated coefficient of trend as a percentage of average acreage for the eriod of analysis; (b) the estimated price elasticity, taken at mean price nd acreage for the period of analysis; (c) the square of the coefficient of ultiple correlation; and (d) the Durbin-Watson statistic.

Table 3 shows that the coefficients of adjustment range between 0.0 for reen Snap Beans to 0.87 for Kale. The zero value for Green Snap Beans,

[30] See footnote 23.

however, is extremely dubious, for with any finite short-run price elasticity of supply an infinite long-run elasticity is implied. It should be recalled, in rejecting the Snap Beans analysis, that the linear supply functions are only approximations useful for the finite ranges of observed price and acreage. When certain characteristics of these data, such as an extremely low coefficient of adjustment, lead to conclusions about characteristics outside the range of observations, the analysis tends to break down. Thus, rather than reject the analysis as a whole, only the conclusion that the long-run elasticity of supply is infinite should be rejected.[31] The analysis which should be rejected in its entirety is that for Artichokes in which a negative, but insignificant, price elasticity of supply is obtained. It is evident that this simple formulation is much too simple in the case of Artichokes.

The final column of Table 3 gives the Durbin-Watson statistics obtained from the calculated residuals of the regressions. No cases of significant serial correlation, either positive or negative, are obtained. If Artichokes are excluded on the other grounds mentioned in the preceding paragraph, only one inconclusive test is obtained, and that for negative,

[31] Many of the crops have extremely low coefficients of adjustment, e.g., Carrots, Cucumbers, Green Peas, Beets, Cauliflower, Celery, and Spinach. Such low coefficients of adjustment imply that the length of the period required for nearly complete adjustment to a change in price is quite long indeed. Under the assumptions of the model used here, of course, complete adjustment occurs only after an infinite amount of time; but 95 per cent of the adjustment or more occurs in a finite time. If N is the number of periods required for adjustment to within 5 per cent of the long-run equilibrium level, N may be determined by the formula

$$(1-\gamma)^N \leq .05,$$

where γ is the coefficient of adjustment. Thus, for example, when γ is 0.5, approximately four years are required for nearly complete adjustment; but when γ is 0.2 approximately 13 years are required, and when γ is 0.1, 27 years are required. In considering the periods required for nearly full adjustment, one should bear in mind two factors: (1) The figure 95 per cent is somewhat arbitrary and so is the dynamic model under consideration. Thus the median adjustment period (i.e., the period over which 50 per cent of the adjustment occurs) may be a reasonably accurate figure, whereas the time required for 95 per cent of the adjustment to take place may be inaccurate, and this even though the estimated long-run elasticity of supply is correct. (2) Furthermore, there are strong reasons for suspecting that the coefficients or elasticities of adjustment are subject to a greater extent than other parameters to what is known as specification bias. (For an explanation of the term *specification bias* and some examples of it see Zvi Griliches, "Specification Bias in Estimates of Production Functions," *Journal of Farm Economics*, Vol. 39 (1957), pp. 8-20.) That is, the estimated coefficients of adjustment are particularly sensitive to the omission of relevant variables. One glance at the variables included in our supply equations is sufficient to show that they omit important variables which should be included. Specification bias in the estimates of γ would, of course, affect both the estimate of the period required for nearly full adjustment and the estimate of the long-run elasticity of supply. See also the discussion between Brandow and Nerlove in the *Journal of Farm Economics*, Vol. 40 (August 1958), pp. 719-728.

not positive, serial correlation. The R^2's range between 0.53 for Shallots and 0.97 for Green Snap Beans, and are 0.9 or better for 11 of the 19 acceptable analyses. The price elasticities of supply for most vegetables are rather low over one production period; however, the picture is reversed if reactions in the long-run are examined. Many vegetables have long-run supply elasticities in excess of one.

Comparison of the trend terms and the Durbin-Watson statistics presented in Table 4 with those presented in Table 3 is significant. The latter are based on what is here called the static approach. Except for Kale, significant positive serial correlation in the residuals is found for every analysis based on the static approach. On the other hand no significant positive serial correlation is found in the residuals of the analyses based on the dynamic approach. To be sure, two tests for serial correlation are inconclusive, but one of them, Artichokes, is for an analysis which has been excluded on other grounds; and the other is an inconclusive test for negative serial correlation and represents a conclusive test for positive serial correlation. For many of the static analyses, indications of strong positive trends are found: for every vegetable except Beets and Artichokes the trend obtained from the static analyses are 1 per cent or greater. On the other hand, the percentage trends obtained from the dynamic analyses are uniformly smaller and some are negative. This result is of value on two counts: (1) Strong trends, either positive or negative, are an indication that a great deal remains to be explained; and (2) strong positive trends do not accord with the casual observation that much vegetable production has shifted from production for fresh market to production for processing. Inasmuch as our analyses deal only with production for fresh market and take no account of the shift resulting from the growth of the frozen food industries, we might expect, at most, very slight positive shifts of the long-run supply schedules for most vegetables.[32]

While more than half of the supply elasticities estimated on the basis of the static approach lie between the one period short-run elasticity and the long-run elasticity estimated in the dynamic analyses, many lie outside this range. For example, the supply elasticity estimated by the static method for lettuce is greater than the long-run elasticity as estimated by our dynamic method. In other cases, the elasticity estimated by the static

[32] For example, Green Peas, which have been significantly affected by the frozen food "revolution," exhibit an unreasonably large positive trend of 1.6 per cent per year under the static approach. In a dynamic analysis this finding is reversed: the supply schedule for Green Peas is found to shift to the left at the rate of 0.2 per cent per year. Other vegetables in the same category are Green Snap Beans, Green Lima Beans, and Spinach. For each of these vegetables the static analyses show strong positive trends, and the dynamic analyses indicate negative trends such as one might expect.

method is less than the one period short-run elasticity as estimated by the dynamic approach. These results show how erroneous conclusions can be if they are based on a static approach, and lend support to the contention, voiced in an earlier paper, that the elasticities estimated by static methods depend crucially on the exact past history of prices and can be anything, depending on what that past history has been.[33]

In the following sections some of the topics suggested by the results of the statistical analyses presented in this section and section 2 above are taken up more generally. First, the question of simultaneous relations among the variables is examined. This discussion is followed by a discussion of serial correlation.

Simultaneous Relations Among the Variables

The methods for estimating long-run elasticities presented in this paper can be extended, in most cases, to apply to situations in which current price and quantity are jointly determined by supply and demand. In the case of supply (see equation (6)), the assumption that expectations of future price are determined primarily by price lagged one year enables estimating long-run elasticities from equation (6) by the method of least squares, provided the residuals are not serially correlated. However, even if the residuals of equation (3) are serially uncorrelated, it may be inappropriate to use least-squares estimates of the coefficients in (3) to estimate long-run elasticities of demand. Whenever current price and quantity are jointly determined by short-run supply and demand, the least-squares estimates of the coefficients in equation (3) are statistically biased. The degree of bias becomes negligible as the price elasticity of short-run supply approaches infinity;[34] and this is one of the reasons why the demand for various items in the United Kingdom was chosen for an initial study of our method. However, in several cases it was observed that the assumption of a perfectly elastic short-run supply broke down and poor results were obtained.

Whenever short-run supply depends on current price and is less than perfectly elastic, standard limited-information or full-information maximum-likelihood methods may be used to estimate the coefficients in the demand equation, provided the coefficients are identified. Consider a system consisting of equation (3) above,

$$(3) \qquad q_t = a\gamma_D + b\gamma_D p_t + c\gamma_D y_t + (1 - \gamma_D)q_{t-1} + u_t,$$

and an equation derived from the long-run supply equation by the methods outlined in section 1,

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[33] See the reference cited in footnote 2.

[34] See Jean Bronfenbrenner, "Sources and Size of Least-Squares Bias in a Two Equation Model," in W. C. Hood and T. C. Koopmans, eds. *Studies in Econometric Method* (New York: John Wiley and Sons, 1953), pp. 221-235.

$$q_t = d\gamma_S + e\gamma_S p_t + f\gamma_S z_t + (1 - \gamma_S)q_{t-1} + v_t. \tag{9}$$

γ_D is the coefficient or elasticity of adjustment appropriate for consumers, γ_s is that appropriate for producers, and z stands for other predetermined variables affecting long-run supply. Equations (3) and (9) jointly determine the current quantity consumed, q_t and the current price, p_t. In the particular case under consideration, y_t, z_t, and q_{t-1} may be considered predetermined and the coefficients in both equations are just-identified. If equation (9) had contained more than one additional variable, the coefficients in (3) would have been over-identified.

When short-run supply is perfectly inelastic, least-squares methods may be appropriate, but not as applied to equation (3). If the long-run quantity demanded depends only on the price of the commodity in question, a model can be developed which shows that the long-run demand elasticities with respect to price and income may be estimated from least-squares estimates of the coefficients in the following equation:

$$\begin{aligned} p_t = {} & \frac{-a\theta}{b} + \frac{1}{b}\,\frac{\theta^2}{1+\theta}\,q_t + \frac{1}{b}\,\frac{\theta}{1+\theta}\,q_{t-1} \\ & - \frac{c}{b}\,\frac{\theta^2}{1+\theta}\,y_t + \frac{c}{b}\,\frac{\theta}{1+\theta}\,y_{t-1} + (1-\theta)p_{t-1} + u_t, \end{aligned} \tag{10}$$

where $\theta = \dfrac{1}{2 - \gamma_D}$ and a, b, and c are coefficients in the long-run demand equation (1).[35] Two major short-comings to this method exist: (1) there are several different ways of deriving the long-run elasticities, and (2) the intercorrelation between q_t and q_{t-1} and y_t and y_{t-1}, is likely to be high; hence, the estimates of the coefficients in (10) may be highly unreliable. Inasmuch as the existence of multiple outlets for most farm products makes it rather unlikely that even these commodities will have perfectly inelastic within-production-period supply to any one consuming sector, this case may be neglected and with it all the concomitant difficulties.

The Problem of Serial Correlation

Perhaps the most significant finding is that the dynamic approach tends to eliminate evidence of positive serial correlation found in the calculated residuals of regressions based on static models. This occurs in a striking and regular manner.

In an examination of a large number of economic time series, Orcutt found that, on the whole, such series exhibit a high degree of autocorrelation.[36] Taken as a "fact of life," the prevalence of serial correlation in eco-

[35] The proof will not be given here.

[36] Orcutt, G. H., "A Study of the Autoregressive Nature of the Time Series Used for Tinbergen's Model of the Economic System of the United States, 1919-1932," *Journal of the Royal Statistical Society* (Supplement), Vol. 111 (1948), pp. 1-52.

nomic time-series leads to serious difficulty in the interpretation of statistical regressions among economic variables. In particular one may often find relationships among variables which give a high degree of explanation, whereas in fact there are no real relationships.[37] But is it necessary to take serial correlation as a "fact of life," and, indeed, isn't its prevalence in economic time-series an interesting phenomenon to be explained, if possible, on economic grounds? The authors believe the dynamic models underlying the statistical results presented in this paper, simple though they are, explain the prevalence of serial correlation in economic time-series, and they do so on economic grounds. On the assumption that producers and consumers do not react instantaneously, to the fullest extent, to changed conditions, it has been shown in a previous paper,[38] that current quantities, both supplied and demanded, are positively related to lagged quantity.[39] The model leading to this result can also be used to show that current and lagged prices are positively related. Little wonder, then, that positive serial correlation has been found in so many economic time-series which are, after all, either quantity series, price series, or combinations thereof.

Because the error or residual terms in the economic relations estimated usually arise from the omission of relevant variables, and because these variables are themselves serially correlated, evidence is frequently found of significant serial correlation in the residuals of estimated economic relations. This is a far more serious problem than the prevalence of serial correlation in the series themselves.[40] The presence of serial correlation in the error terms of economic relationships does not lead, under the most favorable circumstances, to bias and inconsistency of the estimates of the parameters of the relationships, but it does lead to biased estimates of the multiple correlation and the standard errors of the estimated parameters. In many economic relationships lagged values of the dependent variable may be included, and, in this unfavorable circumstance, serial correlation in the error terms does lead to bias and inconsistency of the estimated parameters. Several attempts have been made to deal with the *statistical* problem of serial correlation in the error terms of economic relationships, but none can be said to be truly successful.[41] The authors

[37] See G. U. Yule, "Why Do We Sometimes Get Nonsense Correlations between Time-Series?" *Journal of the Royal Statistical Society*, Vol. 89 (1926), p. 1 ff.

[38] See the reference cited in footnote 2.

[39] See equations (3) and (6) above.

[40] For a relatively nonmathematical account of these difficulties and attempts to deal with them from a statistical point of view, see Marc Nerlove, "Effects of Serial Correlation in the Error Terms," in R. J. Foote, *Analytical Tools for Studying Demand and Price Structures*, United States Department of Agriculture, Agriculture Handbook, No. 146 (August 1958), pp. 148-169.

[41] See D. Cochrane and G. H. Orcutt, "Application of Least Squares Regression to Relationships Containing Auto-Correlated Error Terms," *Journal of the American*

believe that the model which underlies our method not only explains the evidence of a high degree of serial correlation in the residuals of estimated economic relationships, but leads to a solution of the problems raised by this evidence.

The nature of this solution is discussed here only for supply relationships, but it should be noted that the discussion applies equally well to demand relationships. Consider the estimating equation (6) based on our dynamic model and suppose that it represents a "true" relation and that the error terms u_t are independent of one another (i.e., not serially correlated). If one does not take a dynamic approach to the problem of estimating supply functions, one may try to estimate a relationship such as

$$x_t = a' + b'p_{t-1} + c't + u_t'. \tag{7}$$

Now if (6) is the true relation,

$$u_t' = (1 - \gamma)x_{t-1} + u_t. \tag{8}$$

Since, as indicated, x_t tends to be positively serially correlated, x_{t-1} must be also, and so will be the residual terms u_t' of equation (7) suggested by a static approach to supply. Thus, by taking a static approach, one neglects to take account of lagged quantity in the statistical analyses; hence, evidence of serial correlation must be found in the calculated residuals of those analyses. The presence of serial correlation shows up quite well in the static analyses presented in Tables 2 and 4 in the preceding section. On the other hand, by taking a dynamic approach, one does not omit lagged quantity and there is no specific reason for finding evidence of serial correlation in the calculated residuals of these regressions. Examination of Tables 1 and 3 suggests that this is the case.

While the particular dynamic models used in this paper are not perfect representations of economic reality, the results show that a significant contribution to the solution of the problems raised by serial correlation can be made by formulating dynamic economic models of the same general type used here. Treating an *economic* problem as if it were purely *statistical* is not always the best approach.[42]

Statistical Association, Vol. 44 (1949), pp. 32-61; Lawrence R. Klein, *A Textbook of Econometrics* (Evanston: Row, Peterson and Co., 1953), pp. 85-89; and H. Wold, "On Least Squares Regression with Autocorrelated Variables and Residuals, *Transactions of the International Institute of Statistics*, Vol. 32, Part 2 (1949), pp. 277-289.

[42] One of the most usual solutions to the problem of serial correlation in the residuals is the application of the first-difference transformation. See, for example, the reference by Richard Stone cited in footnote 18, pp. 290-291. As Stone points out, the use of first differences surmounts the difficulty only if the residuals, u_t, of the untransformed relationship are generated by the following rather special Markov process:

$$u_t = u_{t-1} + \varepsilon_t$$

where ε_t is an independently distributed error term. In addition to requiring rather special and unusual behavior of the true residual terms, the first-difference trans-

Conclusions

The problem of estimating long-run elasticities of demand and supply has been posed by several previous workers. To date, however, it has not been adequately solved. The present paper applies a solution proposed in an earlier paper to the analysis of the demand for several important groups of commodities in the United Kingdom and to the analysis of the supply of several commerical vegetables produced for fresh market in the United States. Although the dynamic models employed are relatively simple, the use of such models has been found to result in significant improvement as compared with the results of analyses based on static models of behavior.

The methods utilized can be extended to cover cases in which price and quantity are jointly determined by demand and supply. They can also be extended to situations in which supply may be considered as perfectly inelastic in both the short and long runs, but the result of such an extension is not very practical.

The statistical results presented in this paper are primarily illustrative. The principal shortcomings of the demand analyses are the lack of attention to simultaneous determination of price and quantity and too high a degree of aggregation. The major weakness of the supply analyses is the oversimplification of the basic supply relationships. It is to be hoped that this paper will stimulate further research designed to overcome these deficiencies.

The results of the supply analyses presented indicate a wide range of coefficients of adjustment. The investigation of differences among coefficients or elasticities of adjustment appears to be one of the most promising areas of future research.

The most significant finding of the paper is that evidence of positive serial correlation in the residuals of the estimated supply or demand relationships is reduced or eliminated entirely when the suggested methods are employed. The reason for this striking difference between the dynamic and static approaches is explained in terms of the economic significance of the dynamic model employed. The methods presented thus offer an economic solution to a problem which has heretofore been treated in purely statistical terms.

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formation may lead to badly biased coefficients. It is well known that extreme observations in unweighted regression analysis play a greater role in the determination of the slopes of the regression plane than do less extreme observations. Because of the inevitability of unsystematic errors in economic time series, the indiscriminate use of first differences may create extreme observations on the basis of errors alone. Hence, the blind use of first differences in the analysis of economic time series is to be frowned upon.

TOTAL ELASTICITIES—A PREDICTIVE DEVICE*

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THE CONCEPT of elasticity in traditional demand theory permits specifying changes in the quantity of a commodity demanded in response to changes in its price, assuming that prices of other commodities remain constant. But other prices usually cannot remain constant in a free-market situation because prices of related commodities are mutually determined. The elasticity of demand, therefore, is an inadequate basis for predicting actual market behavior. This paper attempts to show how the elasticity of demand can be manipulated to yield a "total demand response curve" that takes account of concurrent changes in prices and quantities of other commodities so that its elasticity will provide a more valid basis for prediction.

Theories are used in economics to predict as well as to explain the effect of a change in one variable on another. Klein, for example, contends that "the real test of the validity and usefulness of any theory is its ability to predict."[1] To be a successful prediction device a theory must approximate the conditions found in reality. The demand concept as formulated by Alfred Marshall and as described in economics texts is more an explanatory than a predictive device and employs restrictions in the form of *ceteris paribus* which are often not applicable to real markets. Marshall defines "The General Law of Demand" in the following manner.[2]

> The greater the amount to be sold, the smaller must be the price at which it is offered in order that it may find purchasers; or, in other words, the amount demanded increases with a fall in price and diminishes with a rise in price. . . . The demand prices in our list are those at which various quantities of a thing can be sold in a market *during a given time under given conditions.*

The concept of demand, when it is defined in the above way, is clear, concise, and easy to understand. It is an analytical tool that can be taught easily to the beginner in economics. The assumption *ceteris paribus* does away with all the vague qualifications of prices of substitutes and comple-

* The writer is indebted to G. E. Brandow, H. M. Southworth, and O. H. Sauerlender of The Pennsylvania State University for their helpful suggestions and criticisms.

[1] Klein, Lawrence, *Econometrics,* Row, Peterson and Company, Evanston, Illinois, 1953, p. 249.

[2] Marshall, Alfred, *Principles of Economics* (8th Ed.) Macmillan and Co., Ltd., London, 1936, p. 84. The quotation is from three paragraphs. The list Marshall refers to is for a hypothetical demand schedule for tea; the italics are Marshall's. While Marshall points out that the desire for a good may be altered by the cheapening of the supply of a rival commodity, he does not explicitly point out that the price of the rival commodity is itself affected by the price of the product in question.

ments. These qualifications are necessary for prediction but are a hindrance in the understanding and use of the concept.

The Total Demand Response Curve

Since in present day economic analysis, the researcher often wishes to evaluate or predict the effect of a change in price on the quantity of a commodity demanded, there is a need for a measure that indicates the responsiveness of a commodity to a change in its price when the actions and interactions of substitutes and complements are taken into account. Such a price-quantity relationship would show, for example, the effect of a change in the price of pork on the quantity of pork demanded, all other *important* variables allowed to act and interact as the market structure requires to reach a new equilibrium level. For lack of a better way to identify this measure and at the same time to differentiate it from the demand curve, this relationship between price and quantity will be called a "total demand response curve." The measure of the responsiveness of quantity to price will be called the "elasticity" of total demand response.

A Description of the Total Demand Response Curve

The total demand response curve can be defined as a schedule of quantities that will be demanded as the price of the commodity under consideration varies, allowing the prices and quantities of complements and substitutes to vary as the market system requires. The elasticity of total demand response measures the percentage change in the quantity of a commodity demanded due to a 1 per cent change in the price of the commodity, allowing all other variables in the market to vary as they must.

The following example will clarify the purpose of the above measure. Suppose a physicist has a block of wood to which are attached a number of springs of different sizes and strengths. The other ends of the springs

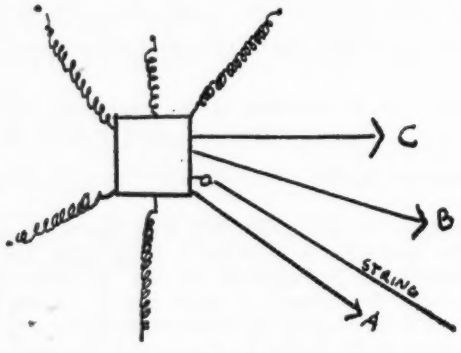

FIG. 1

are attached to immovable posts. At one point on the block the scientist has attached a string as in Figure 1. The physicist proposes to study the movement of the block in response to a force exerted on it by pulling the string in the direction of A. If he makes the assumption that all other forces remain constant, he may predict that the block will move in direction A. However, if he takes into account the forces exerted by the springs, he may predict that it will move in the direction indicated by B. If he takes into account all the forces such as air resistance, gravity, and temperature, he may find the block moving in direction C. The analogy is obvious.

The Marshallian demand concept is represented by movement in the A direction. The total demand response curve attempts to account for the interactions of the important market forces, (the springs of the example), and therefore measures the movement along B. The true movement of the market, taking into account all forces, is represented by C.

If the scientist wished to predict the movement of the block, he would do better to predict it using the theory of the B type of movement rather than the theory of the A type. The same can be said of economics. For prediction purposes, the total demand response curve more closely approximates the actual market movement than does the demand curve and hence is a better predictor. The more exactly we can determine the important variables affecting the commodity under consideration, the better movement B will approximate movement C.

The demand response curve actually represents a series of equilibrium points on the pork demand surface. Such a surface, taking account only

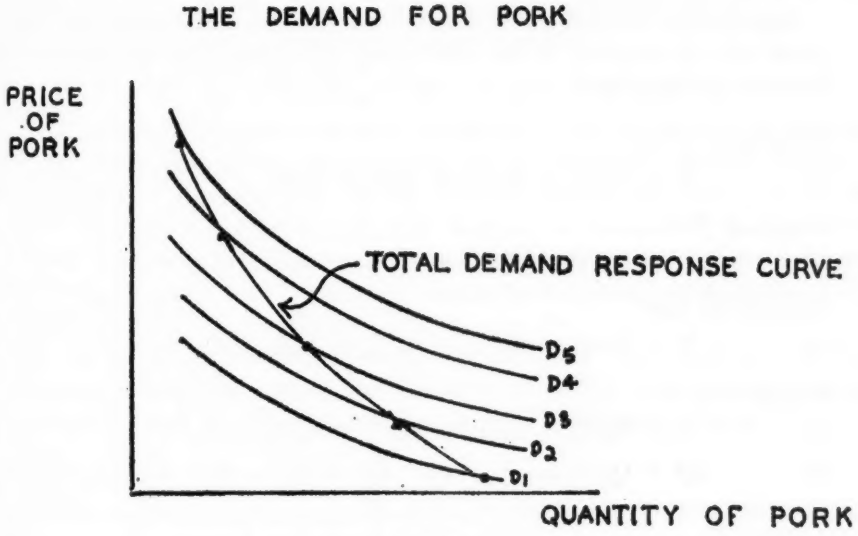

FIG. 2

of the price of beef as an additional variable, can be represented by a diagram (Figure 2) in which the price response curve merely represents a series of equilibrium quantities of pork that will be demanded due to a change in the price of pork, taking into account concurrent changes in the price of beef. From Figure 2 it can be observed that the total demand response curve is merely a path on the demand surface.

A Mathematical Approach to the Total Demand Response Curve

Probably the easiest way to clarify what the total demand response curve is and what it can be used for is to pose a problem, set up the model necessary for the solution of the problem, and show how the model can be manipulated to derive an elasticity of total demand response and a total demand response curve.

The Problem

Suppose the government wished to know what would happen to the quantity of pork demanded or supplied if the price of pork were arbitrarily set at some level dictated by Congress. In order to maintain the price of pork at some level, the government needs to know what amounts of pork it must take off or sell in the market to maintain the desired price.

The answer to this problem requires a knowledge of demand and supply curves and various elasticities.

The Model

Suppose the following set of structural equations represents the meat sector of our economy at the retail level.[3] The equations are assumed to be linear in logarithms.

Demand for Pork

$$(1) \qquad Y_1 = B_{12}Y_2 + B_{14}Y_4 + A_{12}Z_2 + A_{14}Z_4 + C_{11} + U_1$$

Supply of Pork

$$(2) \qquad Y_1 = B_{22}Y_2 + B_{24}Y_4 + A_{21}Z_1 + A_{23}Z_3 + C_{22} + U_2$$

Demand for Beef

$$(3) \qquad Y_3 = B_{32}Y_2 + B_{34}Y_4 + A_{32}Z_2 + A_{34}Z_4 + C_{33} + U_3$$

Supply of Beef

$$(4) \qquad Y_3 = B_{42}Y_2 + B_{44}Y_4 + A_{41}Z_1 + A_{43}Z_3 + C_{44} + U_4$$

$$(5) \qquad Q_s^b = Q_d^b = Y_3 \qquad (6) \quad Q_s^p = Q_d^p = Y_1$$

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[3] Since the purpose of this paper is to demonstrate how the measure can be developed, the model used is merely illustrative, and numerical values are not derived from actual market data.

Where:

Endogeneous	*Exogenous*
Y_1 = Log of Quantity of Pork	Z_1 = Log of Feed Supplies
Y_2 = Log of Price of Pork	Z_2 = Log of Per Capita Income of Consumers
Y_3 = Log of Quantity of Beef	Z_3 = Log of Prices Paid by Farmers for Production Items Other Than Feed
Y_4 = Log of Price of Beef	Z_4 = Log of Retail Prices of Items Other Than Meats

Equations (5) and (6) merely require that in a free market supply and demand be equated in order that the markets be cleared. This system of equations meets the criterion necessary for identification, i.e., that the equations be at least just identified. It is not necessary for the development of the response curves that the equations be just identified, however.

The following numerical values are assumed to have been estimated for the model:

Demand for Pork

(7) $$Y_1 = -.94Y_2 + .72Y_4 + .58Z_2 + .19Z_4 + C_{11}$$

Supply of Pork

(8) $$Y_1 = 1.26Y_2 - .34Y_4 + 1.45Z_1 - .68Z_3 + C_{22}$$

Demand for Beef

(9) $$Y_3 = .45Y_2 - 1.02Y_4 + .90Z_2 - .20Z_4 + C_{33}$$

Supply of Beef

(10) $$Y_3 = -.11Y_2 + .92Y_4 + .83Z_1 - .21Z_3 + C_{44}$$

Because it has been assumed that the equations are linear in logarithms, the coefficients of the structural equations can be interpreted directly as elasticities. For example, the elasticity of demand for pork is $-.94$ and of the supply of pork is 1.26. The elasticity of demand for beef is -1.02 and the elasticity of beef supply is .92. The cross elasticities also can be obtained easily. In (7) the cross elasticity of demand with respect to the price of beef is the coefficient of Y_4, namely .72.

By holding all variables except Y_2 constant at some level (usually their mean values), the supply and demand curves for pork can be obtained from (7) and (8). The equations reduce to the following form:

Demand for Pork

(11) $$Y_1 = K_1 - .94Y_2$$

Supply of Pork

(12) $$Y_1 = K_2 + 1.26Y_2$$

Where:

$$K_1 = .72\bar{Y}_4 + .58\bar{Z}_2 + .19\bar{Z}_4 + C_{11}$$

$$K_2 = -.34\bar{Y}_4 + 1.45\bar{Z}_1 - .68\bar{Z}_3 + C_{22}$$

The effect of a change in the price of pork on the quantity of pork demanded or supplied as given by the above demand and supply functions, however, does not provide us with the solution to the problem faced by the government. A change in the price of pork affects not only the amount of pork demanded but also the amount of beef consumers wish to buy. This change in the demand for beef causes a change in the equilibrium price of beef, which, in turn, reverberates back on the demand for pork. Similar effects occur on the supply side of the market. We need coefficients of Y_2 that take such effects into account.

Derivation of the Total Demand Response Curve and Its Total Elasticity

An arbitrary change in the price of pork implies that Y_2 is no longer an endogenous variable. Therefore, Y_2 must be redefined as an exogenous variable.

(13) $$Y_2 = Z_5$$

Arbitrarily varing the price of pork requires dropping the assumption of (6), $Q_s^p = Q_d^p = Y_1$. The variables are redefined in the following manner:

(14) $$Q_d^p = Y_1$$

(15) $$Q_s^p = Y_5$$

Equations (1), (3), and (4) of the original structure remain the same with the exception of replacing the endogenous variable Y_2 by the exogenous variable Z_5 and the coefficient B_{12} by A_{15}. Equation (2) is replaced by (2′). The set of structural equations appears as follows:

Demand for Pork

(1′) $$Y_1 = .72Y_4 + .58Z_2 + .19Z_4 - .94Z_5 + C_{11} + U_{11}$$

Supply of Pork

(2′) $$Y_5 = -.34Y_4 + 1.45Z_1 - .68Z_3 + 1.26Z_5 + C_{22} + U_{22}$$

Demand for Beef

(3′) $$Y_3 = -1.02Y_4 + .90Z_2 - .20Z_4 + .45Z_5 + C_{33} + U_{33}$$

Supply of Beef

(4′) $$Y_3 = .92Y_4 + .83Z_1 - .21Z_3 - .11Z_5 + C_{44} + U_{44}$$

(16) $Q_d^p = Y_1$ (17) $Q_s^p = Y_5$ (5) $Q_s^b = Q_d^b = Y_3$

This structure allows the price of pork to be varied in any manner desired. Z_5 affects Y_4 as well as Y_1, however, and Y_4 in turn reacts on Y_1.

It becomes apparent that for prediction purposes what is needed is a set of equations that expresses each of the endogenous variables as a function of exogenous variables only. This need is supplied by the reduced form equations. The new set of reduced form equations will contain coefficients for Z_5, and these will show the effect of the price of pork on the quantity of pork demanded and supplied allowing Y_3 and Y_4 to vary as the market structure dictates.

To find the new set of reduced form coefficients, the structural equations may be manipulated through the use of matrix algebra in the following manner.

Let:

$$Y' = [Y_1 \quad Y_5 \quad Y_3 \quad Y_4]$$

$$B = \begin{bmatrix} 1 & 0 & 0 & -B_{14} \\ 0 & 1 & 0 & -B_{24} \\ 0 & 0 & 1 & -B_{34} \\ 0 & 0 & 1 & -B_{44} \end{bmatrix} \qquad A = \begin{bmatrix} 0 & A_{12} & 0 & A_{14} & A_{15} \\ A_{21} & 0 & A_{23} & 0 & A_{25} \\ 0 & A_{32} & 0 & A_{34} & A_{35} \\ A_{41} & 0 & A_{43} & 0 & A_{45} \end{bmatrix}$$

$$Z' = [Z_1 \quad Z_2 \quad Z_3 \quad Z_4 \quad Z_5]$$

$$C' = [C_{11} \quad C_{22} \quad C_{33} \quad C_{44}] \qquad U' = [U_{11} \quad U_{22} \quad U_{33} \quad U_{44}]$$

$$BY = AZ + C + U \tag{18}$$

$$Y = B^{-1}AZ + B^{-1}C + B^{-1}U \tag{19}$$

Let:

$$\begin{aligned} P &= B^{-1}A \\ c' &= B^{-1}C \\ v &= B^{-1}U \end{aligned} \tag{19.1}$$

Then

$$Y = PZ + c' + v \tag{20}$$

The reduced form equations as written in (20) express the endogenous variables as functions of only the exogenous Z's. Since in this example the coefficients in B and A are already known, the p_{ij} matrix can be computed. This matrix contains the coefficients which are required. The reduced form equations follow:

$$Y_1 = -.307Z_1 + .913Z_2 + .078Z_3 + .116Z_4 - .733Z_5 + c_1 \tag{21}$$

$$Y_5 = 1.60Z_1 - .162Z_2 - .718Z_3 + .036Z_4 + 1.159Z_5 + c_2 \tag{22}$$

$$Y_3 = .440Z_1 + .423Z_2 - .111Z_3 - .094Z_4 + .153Z_5 + c_3 \tag{23}$$

$$Y_4 = .432Z_1 + .468Z_2 + .109Z_3 - .104Z_4 + .291Z_5 + c_4 \tag{24}$$

The coefficients of Z_5 (p_{15}) indicate the effect of an increase in the price of pork on the quantities of pork demanded and supplied, and on the

quantity of beef on the market, and on the price of beef. By comparing p_{15} in (21) with A_{15} in (1′), one can see that the response of pork demand to a change in the price of pork has been reduced from $-.94$, (A_{15}) to $-.733$, (p_{15}). The effect of the price of pork on the price of beef is indicated by p_{45}. This coefficient indicates that in the above example a 1 per cent change in the price of pork causes a .291 per cent change in the price of beef.

The total demand response curve can be written in the following form:

Total Demand Response Curve

(25) $$Y_1 = K_1 - .733Z_5$$

Total Supply Response Curve

(26) $$Y_5 = K_5 + 1.159Z_5$$

These two equations are depicted graphically in Figure 3. Equations (25) and (26) can be solved for the price $\dot{Z}_5$ that will just clear the market, i.e., $Y_1 = Y_5$. The quantity of pork the government would be required to sell in the market or remove from the market in order to use the market mechanism to establish a price arbitrarily set at the level p by Congress also can be predicted by solving (27).

(27) $$Q = Y_1 - Y_5 = K_1 - K_5 - (.733 + 1.159)Z_5$$

Where $Z_5 = \log p$

The antilog of Q will be the amount of pork the government must buy or sell or a shortage requiring rationing.

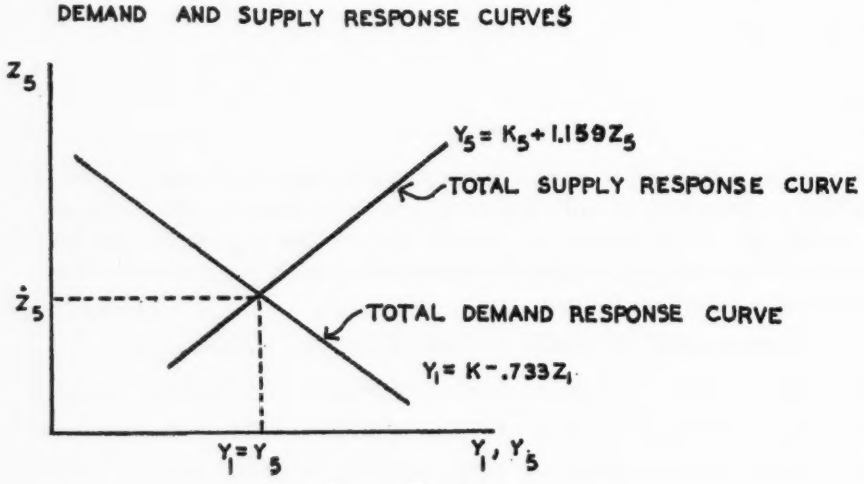

FIG. 3

A Further Examination of the Elasticity of Total Demand Response

The previous analysis has shown how the elasticity of total demand response and the total demand response curve can be obtained from a statistically estimated economic model. Further insight into the elasticity of total demand response can be obtained by determining exactly how the elasticity of total demand response is affected by structural coefficients.

It is convenient for this purpose to begin with p_{45}. p_{45} was defined earlier as the effect of a 1 per cent change in the price of pork on the price of beef. The solution of (19.1), $P = B^{-1} A$, gives p_{45} in terms of the structural coefficients:

$$p_{45} = \frac{A_{45} - A_{35}}{B_{34} - B_{44}} \tag{28}$$

where,

A_{45} = The cross elasticity of supply for beef w.r.t. the price of pork.
A_{35} = The cross elasticity of demand for beef w.r.t. the price of pork.
B_{34} = Elasticity of demand for beef.
B_{44} = Elasticity of supply of beef.

It can be observed from (28) that the price of pork has the greatest effect on the price of beef when the price of pork has a large effect on beef supply and demand and when beef supply and demand are inelastic.[4]

In the case of competing products the numerator and denominator are both negative; hence p_{45} is positive. It is only in the case of commodities which are substitutes on one side of the market and complements on the other side of the market that the sign of p_{45} becomes doubtful.

The limits on the size of p_{45} can also be determined quite easily. The numerator of (28) contains cross elasticities and the denominator contains direct elasticities. In the usual case, cross elasticities are less than direct elasticities. Hicks says that equilibrium in multiple markets requires that the cross elasticities of demand must be less than the corresponding direct elasticities.[5] Therefore, p_{45} is less than one.

Next we can examine p_{15}, which is the elasticity of total demand response for pork. The solution of (19.1) yields the desired relationship. Substituting $B_{11} = 1$ and clearing signs, one gets the following relationship:

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[4] A large effect of the price of pork on beef demand and supply implies considerable substitution between pork and beef. Therefore one would not expect the elasticity of beef demand and supply to be low when the cross elasticities are high.

[5] Hicks, J. R., *Value and Capital*, Oxford University Press, 1939, Chapter 5, and Mathematical Note 14, pp. 315-16.

$$p_{15} = A_{15} + B_{14}\frac{A_{45} - A_{35}}{B_{34} - B_{44}} = A_{15} + B_{14}p_{45} \tag{29}$$

where,

p_{15} = The elasticity of total demand response for pork
A_{15} = The elasticity of demand for pork
B_{14} = Cross elasticity of demand for pork with respect to the price of beef
p_{45} = The effect of a 1 per cent change in the price of pork on the price of beef

The elasticity of total demand response is seen to be the sum of two terms: one of these terms is the ordinary demand elasticity; the other is the cross elasticity of demand for pork with respect to the price of beef multiplied by the elasticity of the price of beef with respect to the price of pork.

If competing commodities are involved, as here, $|p_{15}|$ will be less than $|A_{15}|$ because B_{14} and p_{45} are both positive. This means that the elasticity of total demand response is less than the demand elasticity.

In a stable market where direct elasticities exceed cross elasticities, $|A_{15}| > |B_{14}|$, and since $p_{45} < 1$, p_{15} will be negative. Therefore the elasticity of total demand response, like ordinary demand elasticity, is usually negative.

Further Observations

Although the model used involved only two commodities, the analysis of an elasticity of total demand response can be easily extended to any number of commodities. For example, it can be shown that for three commodities, such as pork, beef, and chicken, the elasticity of total demand response is defined by the following equation:

$$p_{15} = A_{15} + B_{14}p_{45} + B_{16}p_{65} \tag{30}$$

where:

p_{15}, A_{15}, B_{14}, and p_{45} are defined as in (29) and:
B_{16} = The cross elasticity of demand for pork w.r.t. the price of chicken.
p_{65} = The effect of a 1 per cent change in the price of pork on the price of chicken.

It can be observed that each commodity added to (30) will increase the difference between ordinary demand coefficients and total demand response coefficients, provided the markets involved are stable.

The same type of analysis also can be applied to the supply response curve. It can be shown that under usual market conditions the elasticity

of total supply response will also be less elastic than ordinary supply elasticity.

Summary

This paper has attempted to demonstrate how demand and supply relationships can be manipulated to approximate adjustments under real market conditions so that they can be used as prediction devices. The total demand response curve and the elasticity of total demand response accomplish this purpose. With the aid of econometric techniques, these measures were derived and some of their implications explored. Knowing the composition of the demand response curve and how the elasticities and cross elasticities are reflected in the elasticity of demand response enables the researcher to make better estimates of what will be the effect of price on quantity.

SHORT RUN EFFECTS FOLLOWING CONTROLLED PRICE CHANGES: SKIM MILK

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THIS paper outlines the structure, analysis and findings of a controlled experiment in which the price of skim milk sold by a dairy at Storrs, Connecticut, was varied according to a predetermined plan throughout the four-year period 1951-1955. This experiment, part of a research project sponsored by the Storrs Agricultural Experiment Station, was designed to test the popular belief that the demand for fluid skim milk is highly inelastic with respect to price.[2] With the experimental design employed, it was also possible to define alternative "short run" periods, and to illustrate the impact of time, measured from the occurrence of price changes, upon the price elasticity of demand for this product.[3]

The Dairy and the Market

The cooperating dairy, the University of Connecticut Creamery, offered skim milk only on a special order basis prior to the autumn of 1951.[4] In September of that year, fresh fluid skim milk was added as a regular retail product, and the Dairy agreed to set and maintain the price differential between skim milk and whole milk according to the schedule shown in Table I.[5] Price differentials between whole and skim milk, rather than absolute skim prices, were varied to reduce complications when prices for whole milk and other dairy products changed.[6] However, the price of whole milk set by the Dairy remained almost unchanged for the duration

[1] A critical reading by Robert Summers disclosed several inadequacies in an earlier draft of this paper. He is in no way responsible for errors of technique or judgment which may remain.

[2] Other publications based on this project include: Donald J. Baker and Charles H. Berry, "The Price Elasticity of Demand for Fluid Skim Milk," *Journal of Farm Economics*, Vol. 35, February 1953; Charles H. Berry, *et al*, "The Demand for Fluid Skim Milk," Storrs Agricultural Experiment Station Bulletin 325, May 1956; and George K. Brinegar and Stewart Johnson, "The Market for Fluid Skim Milk," Storrs Agricultural Experiment Station Bulletin 303, July 1953.

[3] Sales of skim milk now amount to approximately 3.1 per cent by volume of fluid whole milk sold at retail in markets controlled by Federal Orders. In these markets sales of skim milk exceed those of chocolate milk by about 30 per cent.

[4] The University Creamery is hereafter referred to as "the Dairy."

[5] Price changes were announced two or three days in advance by "bottle-collars" on delivered milk, and by a poster in the Dairy's retail store.

[6] The Dairy, a University-owned establishment, has traditionally priced milk products to coincide with prices set by other dairies in the area to avoid the charge of "unfair competition." Except for skim milk, the Dairy made no change in this basic policy throughout the four years studied.

of the experiment, and a home-delivered price of 23 cents a quart was effective from July 1, 1951, to July 1, 1955, except during August through December 1952 (24 cents), and April through June 1953 (22 cents). The changes in price differentials were therefore closely related to the actual changes in the price of skim milk during the period studied (Table I).

TABLE 1. PRICES IN CENTS PER QUART FOR SKIM AND WHOLE MILK AND THE DIFFERENTIALS MAINTAINED BY THE UNIVERSITY DAIRY FROM OCTOBER 1951 TO MAY 1955*

Year and Month	'51–'52			'52–'53			'53–'54			'54–'55		
	Whole	Skim	Diff.	Whole	Skim	Diff.	Whole	Skim	Diff.	Whole	Skim	Diff.
Oct.	23	17	6	24	22	2	23	15	8	23	19	4
Nov.	23	17	6	24	22	2	23	15	8	23	19	4
Dec.	23	21	2	24	16	8	23	19	4	23	17	6
Jan.	23	21	2	23	15	8	23	19	4	23	17	6
Feb.	23	19	4	23	17	6	23	21	2	23	15	8
Mar.	23	19	4	23	17	6	23	21	2	23	15	8
Apr.	23	15	8	22	18	4	23	17	6	23	21	2
May	23	15	8	22	18	4	23	17	6	23	21	2

* Summer months were not included because many otherwise permanent members of the community are away for a month or more during the vacation period.

The Dairy operates a retail store and also offers a regular "alternate-day" delivery service to customers with charge accounts.[7] Other dairies make deliveries to homes in Storrs, and competing milk is available from grocery stores in the area. The gross value of sales of all products by the University Dairy averaged roughly $60,000 per year from 1951 to 1955. The University Dairy dominates the parts of the Storrs market it serves, providing over two-thirds of the milk purchased.

Storrs is a university community of about 1,000 permanent residents and, at the time of this experiment, approximately 6,000 students. These students, with minor exceptions, live and eat in University buildings. Sales of milk to these and other University dining halls and cafeterias, as well as to privately-owned restaurants, were excluded from the data discussed below. The basic market considered included roughly 1,000 persons, most of whom were associated (*not as students*) either directly or indirectly with the University of Connecticut.

Tabulation of Data

Sales of skim milk, chocolate milk, and whole milk were recorded for each day of the four-year period covered. These sales were classified according to type of payment (cash or charge), and origin of sale (cus-

[7] A discount of 1 cent a quart is allowed at the Dairy's retail store.

tomer's residence or dairy store). These data were analyzed in the aggregate and also separately by the categories of charge account sales, cash sales, route sales, store sales and combinations thereof. In addition, data for the periods immediately following each price change were considered independently of data relating to later or "longer run" periods. In the extreme, since home deliveries were made only on every second day, it was possible to consider each two-days' data separately, each representing a different 48 hour time-period with respect to a change in price, and to describe with some precision Marshall's concept of "time" by the pattern of demand parameters resulting from this breakdown.

Design of Experiment

The design of the experiment, a Latin Square, required that each price differential (treatment) occur once in each year (column) and once in each two-month price-period (row).[8] The distribution of treatments is random subject to these restraints. The model, in this case a 4×4 square, takes the form

$$Y_{ijk} = m + a_i + b_j + c_k + e_{ijk} \tag{1}$$

where, i,j,k, = 1...4, Y_{ijk} = the observed level of skim milk sales, m = a constant, a_i = the effect of the i^{th} year, b_j = the effect of the $_j{}^{th}$ period within years, c_k = the effect of the k^{th} price differential or treatment, and e_{ijk} = a randomly distributed error with a mean of zero and a constant variance, σ^2. This model suggests an analysis of variance; though with the 4×4 square, freedom is not great.

Of 15 degrees of freedom, nine represent differences among prices, among years and among two-month periods within years. Six remain to provide an unbiased estimate of error (σ^2) in the comparison between prices. This design will be efficient only if the year (trend) *and* two-month (seasonal) effects are significant. Otherwise a simpler design with fewer restraints on the random distribution of treatments within "blocs" and with the resulting increase in freedom for the estimation of error variance is more appropriate.

In the application of this analysis to the data described above, sales of skim milk were first expressed as percentages of the corresponding sales of whole milk to correct for changes in the number of Dairy customers throughout the four years.[9,10] A preliminary three-way analysis of vari-

[8] See R. A. Fisher, *Statistical Methods for Research Workers*, (Hafner, 1950), pp. 267-270; and also Oscar Kempthorne, *Design and Analysis of Experiments*, (Wiley, 1952), pp. 217-233.

[9] A small bias is introduced by this procedure if sales of skim milk replace sales of whole milk which otherwise would have occurred; however, the resulting distortion can readily be shown to be, at most, of second order importance, as is non-

ance revealed that although the year effect was highly significant, the effect of two-month periods (seasonal) was not. The price effect was not found to be significant when six degrees of freedom were eliminated through correction for both years (columns) and two-month periods (rows). The effect of price was, on the other hand, "significant" with a simpler two-way analysis when correction was made only for the column (year) effect, and when nine rather than six degrees of freedom were available for the estimation of error variance.[11] However, to ignore the row effect at this point means that the assumptions of the model have in part been derived from the same data against which these assumptions are to be tested. Nevertheless, this latter procedure is implicit in the following analysis, and as a consequence the confidence limits shown are somewhat understated and should be interpreted with this procedure in mind.

The impact of price in this two-variable analysis is described below in terms of price elasticities derived from linear regression coefficients estimated by fitting the least squares regression

$$Y = \alpha_1 X_1 + B_1 Z_1 + B_2 Z_2 + B_3 Z_3 + B_4 Z_4 + u \tag{2}$$

where Y is the ratio of skim milk sales to whole milk sales, X is the skim to whole milk price differential, Z_1 is unity in year one and zero otherwise, Z_2 is unity in year two and zero otherwise, Z_3 is unity in year three and zero otherwise, Z_4 is unity in year four and zero otherwise and α_1, B_1, B_2, B_3 and B_4 are constants. This model is a simple extension of the two-way analysis of variance discussed above. Price elasticities shown were estimated at the mean values of the price and sales variables by the expression $\eta = \alpha_1 \frac{3.4\bar{X}}{Y}$ Confidence limits for these elasticities were derived directly from the standard errors of the regression coefficients and do not take into effect sampling error of the variable Y.[12]

An alternative analysis was also applied, resulting in identical point estimates, but slightly different confidence limits as shown by Table II.

linearity, given the observed variation in skim milk sales. This statement holds only if skim sales are small relative to sales of whole milk.

[10] For the most part, sales of chocolate milk were ignored. In several cases, however, the analysis was repeated with skim milk sales first expressed as percentages of the corresponding total of whole *plus* chocolate milk sales. The findings with this approach did not differ appreciably from those derived from the simpler procedure of ignoring chocolate milk, once again because skim sales were not large relative to sales of whole milk.

[11] The Latin Square is treated here as a randomized bloc with the assumed model: $Y_{ik} = m + a_i + c_k + e_{ik}$.
Symbols are defined as above. Eliminating consideration of the factor bj of equation (1) releases three degrees of freedom, increasing the freedom associated with the estimation of the error term from six to nine.

[12] The factor 3.4 is necessary if the results of this experiment are to be presented

TABLE 2. PRICE ELASTICITIES OF DEMAND FOR SKIM MILK:
(point estimates with alternative .95 confidence limits[1])

Time Period[2]	Total Sales			Total Store Sales		
	Point Estimate	Limits		Point Estimate	Limits	
1. Two months	1.08	± .54	± .61	1.40	± .82	± .98
2. One month						
1st	.86	± .56	± .64	1.00	± .81	±1.00
2nd	1.29	± .59	± .64	1.78	± .94	±1.06
3. Four days						
1st	.26	± .74	± .89	.11	±1.40	±1.69
2nd	.55	± .80	± .84	.38	±1.06	±1.24
3rd	1.03	± .73	± .75	1.25	±1.09	±1.17
4th	.82	± .69	± .69	.95	±1.00	±1.12
5th	1.14	± .72	± .86	1.27	±1.11	±1.17
6th	1.12	± .62	± .84	1.46	±1.11	±1.11
7th	1.18	± .46	± .57	1.76	± .99	±1.12
8th	.86	± .92	± .96	1.21	±1.43	±1.45
9th	1.53	± .61	± .59	1.91	±1.03	±1.04
10th	1.12	± .64	± .64	1.99	±1.03	±1.08
11th	1.32	± .68	± .72	1.88	± .97	±1.04
12th	1.29	± .76	± .74	1.66	±1.22	±1.07
13th	1.03	± .59	± .79	.90	±1.11	±1.52
14th	1.50	± .42	± .51	2.29	± .78	± .92
4. Two days						
1st	− .16	± .85	± .91	− .89	±1.74	±1.90
2nd	.66	± .75	± .91	.95	±1.47	±1.60
3rd	.44	± .94	± .93	.03	±4.71	±1.48
4th	.63	± .82	± .92	.52	±1.46	±1.66
5th	.90	± .92	± .92	1.16	±2.06	±1.93
6th	1.19	± .85	± .86	1.61	±1.34	±1.42
7th	.82	± .59	± .61	.76	±1.39	±1.43
8th	.81	± .97	± .92	1.06	±1.56	±1.59
9th	1.26	± .70	± .71	1.41	± .93	±1.17
10th	1.05	± .95	± .93	1.23	±2.08	±1.98
11th	1.14	± .71	± .78	1.47	± .94	±1.07
12th	1.10	± .66	± .64	1.51	±1.39	±1.37
13th	1.25	± .46	± .68	2.01	± .89	±1.29
14th	1.13	± .64	± .62	1.55	±1.46	±1.44
15th	.71	±1.17	±1.14	1.18	±2.75	±2.53
16th	1.03	± .94	± .99	1.50	±1.15	±1.34
17th	1.80	± .79	± .67	2.42	±1.35	±1.21
18th	1.32	± .64	± .74	1.77	±1.60	±1.60
19th	.96	± .82	±1.01	1.68	±2.36	±2.84
20th	1.33	± .93	± .73	2.41	±1.90	±1.59
21st	1.40	± .71	± .78	1.89	±1.29	±1.31
22nd	1.18	± .93	± .87	1.60	±1.52	±1.43
23rd	1.25	± .74	± .74	1.50	±1.94	±1.69
24th	1.36	± .92	± .88	1.79	±1.55	±1.47
25th	1.41	± .60	± .96	1.68	±1.23	±1.79
26th	.63	±1.01	± .93	− .02	±1.82	±1.74
27th	1.71	± .59	± .65	2.86	±1.55	±1.59
28th	1.31	± .54	± .58	1.84	± .81	± .87
29th	1.23	± .76	± .79	1.84	±1.35	±1.44

[1] Confidence limits shown first (left hand column) are based on model (2). The second set (right hand column) are based on model (3). See text.

[2] Data for each time period were considered independently. For example, the estimate for the first four-day period is based on 16 observations, where each sales observation is the four-day total for the first four days immediately following the corresponding change in price.

TABLE 2 (*Continued*)

Time Period	Charge Account Sales					
	Store			Route		
	Point Estimate	Limits		Point Estimate	Limits	
1. Two Months	1.59	± .82	± .83	.85	± .87	± .80
2. One Month						
1st	1.27	± .77	± .81	.76	± .97	± .89
2nd	1.90	±1.03	±1.01	.93	± .82	± .75
3. Four Days						
1st	.67	±1.51	±1.54	.33	±1.07	± .98
2nd	.09	± .96	±1.07	.65	±1.13	±1.07
3rd	1.02	± .62	± .71	.88	±1.06	± .98
4th	1.73	±1.22	±1.31	.81	±1.03	± .90
5th	1.44	±1.37	±1.30	.99	±1.14	±1.00
6th	1.90	±1.07	±1.03	.91	± .97	± .91
7th	1.96	±1.08	±1.10	.77	± .98	± .79
8th	1.74	±1.62	±1.53	.62	±1.03	± .99
9th	1.97	±1.25	±1.20	1.20	± .98	± .86
10th	2.44	±1.11	±1.10	.66	± .93	± .89
11th	1.53	±1.27	±1.10	.94	± .93	± .89
12th	1.75	±1.16	±1.01	.98	± .88	± .92
13th	1.16	±1.10	±1.30	1.16	± .82	± .75
14th	2.23	±1.00	± .93	.85	± .68	± .60
4 Two Days						
1st	− .36	±2.10	±1.97	.35	±1.12	±1.03
2nd	1.52	±1.76	±1.73	.32	±1.07	± .97
3rd	− .63	±1.67	±1.44	.67	±1.24	±1.24
4th	.42	±1.34	±1.60	1.44	±1.77	±1.60
5th	1.10	±1.59	±1.55	.80	± .94	± .86
6th	1.11	±1.22	±1.28	.89	±1.19	±1.09
7th	1.90	±1.81	±1.92	.85	±1.03	± .86
8th	1.37	±1.92	±1.84	.77	±1.09	± .98
9th	1.57	±1.58	±1.74	1.02	±1.22	±1.04
10th	1.16	±2.38	±2.29	.96	±1.09	±1.02
11th	2.39	±1.03	±1.05	.83	± .92	± .85
12th	1.58	±2.07	±1.96	.99	±1.04	± .98
13th	2.25	±1.15	±1.20	.75	± .89	± .83
14th	1.83	±1.54	±1.66	.80	± .71	± .81
15th	1.96	±2.46	±2.25	.55	± .96	± .99
16th	1.70	±1.62	±1.57	.70	±1.17	±1.06
17th	2.87	±1.59	±1.55	1.38	±1.08	± .94
18th	1.37	±1.83	±1.63	1.03	±1.01	± .91
19th	1.70	±2.51	±2.86	.59	±1.02	± .99
20th	3.26	±2.21	±1.96	.73	± .93	± .88
21st	1.23	±1.48	±1.46	.94	± .92	± .86
22nd	1.78	±1.92	±1.77	.93	± .98	± .97
23rd	1.41	±1.69	±1.49	1.04	± .88	±1.04
24th	1.93	±1.24	±1.17	.91	± .97	±1.11
25th	1.84	±1.23	±1.55	1.13	± .66	± .68
26th	.36	±1.93	±1.94	1.17	±1.04	± .90
27th	2.56	±2.21	±2.07	.92	± .66	± .57
28th	2.02	±1.23	±1.01	.78	± .71	± .64
29th	2.30	±1.40	±1.32	.95	± .68	± .57

TABLE 2 (*Continued*)

Time Period	Total Cash Sales			Total Charge Account Sales		
	Store Only			Store and Route		
	Point Estimate	Limits		Point Estimate	Limits	
1. Two Months	.91	±1.26	±1.63	1.10	± .57	± .56
2. One Month						
1st	.36	±1.22	±1.61	.93	± .61	± .59
2nd	1.43	±1.45	±1.80	1.26	± .82	± .58
3. Four Days						
1st	−1.40	±2.29	±2.90	.44	± .84	± .95
2nd	1.03	±1.72	±1.88	.43	± .82	± .78
3rd	1.67	±2.22	±2.37	.91	± .69	± .66
4th	− .60	±1.79	±1.76	1.08	± .71	± .66
5th	.84	±1.29	±1.73	1.16	± .76	± .69
6th	.54	±2.22	±2.22	1.26	± .62	± .63
7th	.71	±1.87	±1.95	1.18	± .54	± .52
8th	.06	±1.63	±1.83	1.00	± .94	± .93
9th	1.70	±1.77	±2.03	1.50	± .66	± .60
10th	.78	±2.13	±2.31	1.18	± .60	± .60
11th	2.57	±1.07	±1.92	1.13	± .77	± .70
12th	1.16	±2.12	±2.02	1.27	± .71	± .73
13th	.30	±2.17	±2.67	1.16	± .57	± .68
14th	2.35	±1.20	±1.71	1.31	± .42	± .39
4. Two Days						
1st	−1.75	2.36	2.94	.08	1.01	± .91
2nd	−1.53	3.92	4.05	.77	.83	± .89
3rd	1.21	2.10	2.51	.29	1.01	± .91
4th	1.07	2.40	2.40	.56	.77	± .83
5th	1.32	3.57	3.71	.91	.79	± .72
6th	2.62	2.54	2.47	.94	.87	± .85
7th	−1.29	2.04	1.92	1.22	.60	± .61
8th	.15	2.28	2.29	.93	.99	± .86
9th	1.81	2.08	1.91	1.28	.87	± .86
10th	1.88	3.17	3.34	1.03	.89	± .79
11th	.11	2.73	2.67	1.38	.75	± .75
12th	1.10	3.35	3.12	1.14	.69	± .68
13th	.54	2.66	3.19	1.24	.66	± .67
14th	.20	3.11	2.89	1.14	.57	± .52
15th	.03	4.04	3.67	.92	1.04	±1.01
16th	.95	2.52	2.81	1.08	.96	± .94
17th	1.32	2.58	2.49	1.90	.83	± .75
18th	2.83	2.84	3.17	1.14	.74	± .69
19th	1.49	3.36	3.69	.91	.75	± .88
20th	.33	2.44	2.46	1.47	.81	± .67
21st	3.13	1.68	2.52	1.04	.71	± .65
22nd	.89	2.76	2.67	1.21	1.01	± .95
23rd	1.39	3.32	2.95	1.18	.65	± .70
24th	1.46	3.38	3.54	1.36	.84	± .83
25th	1.57	2.37	2.95	1.39	.59	± .77
26th	−1.16	2.86	2.94	.90	.91	± .89
27th	3.22	1.87	2.59	1.40	1.32	±1.22
28th	1.46	1.10	1.57	1.27	.67	± .59
29th	1.27	2.23	2.51	1.36	.68	± .63

Here the more usual multiple regression model

$$Y = \alpha_0' + \alpha_1'X + \alpha_2T + e' \tag{3}$$

was employed with T measured in 16 two-month periods from the beginning of the experiment (i.e. T = 1. . . 16). This model imposes a linear restraint on the correction for years, but in addition assumes that the "seasonal" dismissed by the earlier model is in fact a simple linear extension of the year effect.[13] These two models are the basis of the statistics presented for each class of data in the following sections of this paper.

Findings

Table II contains estimates of the price elasticity of demand for skim milk for a variety of time-periods and for six classes of skim milk sales.[14] Two sets of confidence limits are shown, one set corresponding to each of the two models discussed above.[15] These estimates are, on the whole, higher for store sales than for route sales, and more reliable for charge account sales than for cash sales. This is not surprising. Route customers typically have standing orders not as subject to day-to-day change as store purchases where the customer is confronted by relative prices at the time of each sale rather than once a month as is true, in effect, for

as conventional price elasticities showing the percentage change in quantity demanded associated with a 1 per cent change in the *absolute* price of skim milk. A 1 cent change in the price of skim milk is a greater percentage of the price differential between skim and whole milk than of the absolute price of skim. In this experiment the mean price of skim milk equalled 3.4 times the mean price differential (X). It is for this reason that the factor 3.4 is necessary in the foregoing expression which is in this instance an approximation of the conventional definition of the price elasticity of demand for skim milk. Error will be present to the extent that the cross elasticity of demand between skim and whole milk is high (and this error will be greater the larger skim milk sales are relative to sales of whole milk), and to the extent that the price of whole milk varies. In this experiment error can be expected to be low, as a little arithmetic on the part of the reader will verify. Skim sales were not large relative to whole milk sales, making the quantitative impact of even a one-quart-for-one-quart between whole and skim milk negligible, and, in the second case, the price of whole milk did remain almost unchanged during the four-year period.

[13] Note that since the design of the experiment precludes an association between time (t) and price (X), α_1' must equal α_1. Differences between the empirical results derived from the application of the two models is therefore confined to confidence limits. See Table II.

[14] For convenience, elasticities have been shown without negative signs. Where negative signs do appear, this indicates that the observed association between quantity demanded and price was positive.

[15] Neither set of limits is consistently narrower than the other. Limits based on model (3) would be expected to be smaller if the seasonal were simply a "within-year" trend. Limits based on (2) would be smaller if this were not the case and if the year-to-year trend were not adequately approximated by the linear assumption. Table II shows that neither (2) nor (3) is clearly more appropriate than the other in all cases.

housewives whose milk is delivered.[16] Cash sales probably contain a disproportionately large number of irregular or unplanned purchases—purchases by transients and persons who experience temporary difficulty with local sources of milk other than the University Dairy.

The impact of time, measured from the day of the price change, is quite evident and regular for each category of sales other than, perhaps, cash sales. Chart I suggests that the impact of a price change upon the quantity of skim milk demanded is, or is almost, negligible immediately following the price change, and thereafter increases, but at a decreasing rate.[17] Arithmetically this may be described by the model (3) above with the added assumption

$$\alpha_1' = \gamma_0 + \gamma_1 t + \gamma_2 t^2 \tag{4}$$

where t is the Marshallian notion of time or "run" (time measured in days from each price change). This model reduced to the single equation

$$Y = \alpha_0' + \gamma_0 X + \gamma_1 Xt + \gamma_2 Xt^2 + \alpha_2 T + u' \tag{5}$$

which, in the absence of autocorrelation in the error terms, might be fitted directly to the data of this experiment. However, successive four-day periods are not independent in this case (possibly eight–day periods might be), biasing estimates of the standard errors of regression coefficients derived in this fashion.[18] Note that the information presented in chart form above suggests that γ_0 would be close to zero, γ_1 positive and γ_2 negative, bearing out the usual assumptions made with respect to changes in the price elasticity of demand as the length of run increases.[19]

Concluding Remarks

The potential of the application to economic data of the techniques of controlled experiment has long been debated, often dismissed, yet seldom tested. The foregoing reports just such an experiment. The findings bear both on the quantitative nature of the response of sales of skim milk to

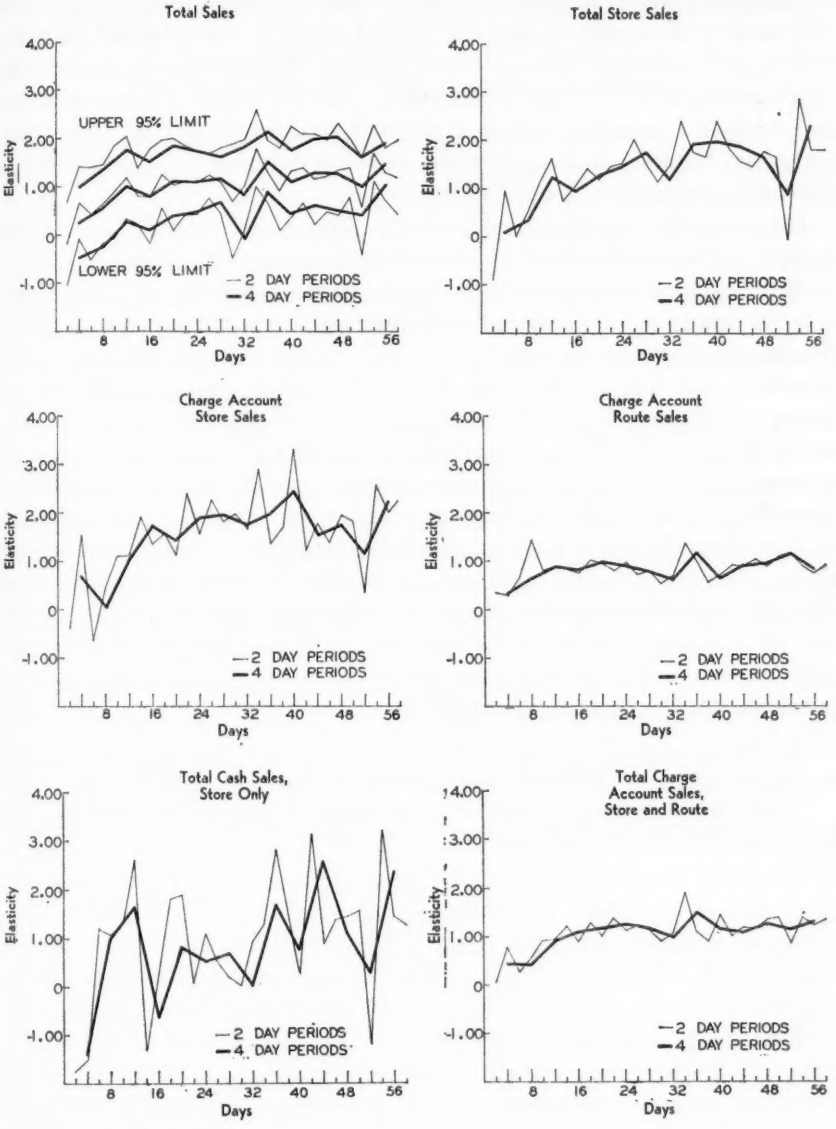
[16] Customers could change orders for delivered milk only by contacting the Dairy store directly; routemen were not authorized to make such changes.

[17] The pattern is most evident in the case of store sales, indicating that if, in the long run, there is no difference between the behavior of store and route customers, then the long run is "shorter" for store sales than for route sales.

[18] Employing first-differences of sales and prices was also inadvisable in this case because the price of skim milk was inappropriate during the months of September.

[19] One further test was completed for the category of total sales. The model (3) was fitted to all 224 observations of four-day sales data, and the sum of squares error about this single regression compared to the total sum of squares about the 14 regressions employing this same model which were fitted to obtain the 14 independent estimates shown for this category in Table II. The reduction in sum of squares error which results from fitting fourteen regressions, as opposed to one, is significant at the .001 level.

CHART I. PRICE ELASTICITIES OF DEMAND FOR SKIM MILK*



* Source: Table II

changes in price in the Storrs area and also upon the pattern of change in this relationship as time or length of "run" increases.

Several factors appear which may limit the general applicability of the former. The community at Storrs, Connecticut, is small and unique. Oper-

ationally, members of that community are not a sample representative of the milk-consuming public at large. The University Dairy was not the sole source of supply during the period studied. The elapsed time between price changes was only two months. Probably many individuals were aware, after the first few months, that the price of skim milk was behaving in a peculiar fashion, and acted accordingly.[20] The reader must judge for himself, at this point, the extent to which these factors negate the value of these numerical findings.[21]

However, the empirical value of the experiment extends beyond this aspect of these estimates. The results of a comparison of demand parameters from one time period to another may be generally applicable even though this is not true of the individual estimates themselves. A prime advantage of the work reported here is that the length of run can be specified, and that a legitimate comparison made among elasticities relating to different time periods, a comparison which does not necessarily suffer because the Storrs community is an isolated example. It must be evident that measures of short run elasticities can be no more meaningful than the precision with which time periods are measured in the collection of basic data. Without rigor at this level, intelligent comparisons among the measures of different studies simply cannot be made. It is at this level that the controlled experiment has its greatest advantage. With cooperation on a broader and more ambitious scale, this technique could be employed with these advantages to provide estimates of demand parameters less subject to the limitations noted above.

[20] Several of these persons were sufficiently aware to complain rather forcefully to the University Dairy when skim milk was priced only 2 cents below whole milk.

[21] There is no inconsistency between the estimates reported in this paper and those found elsewhere in the literature. See page 1, footnote 1.

AN EVALUATION OF SOME ECONOMIC FACTORS AND FARMERS' ATTITUDES THAT MAY INFLUENCE ACCEPTANCE OF SOIL CONSERVATION PRACTICES*

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DURING the past 20 years United States agriculture has received substantial government aid in the form of technical advice and services, materials, and incentive payments for the establishment of soil conservation practices. This tremendous program of public assistance has been available to the individual farmer on a voluntary basis. Since the success of this conservation program depends upon the farmer's acceptance of the recommended practices, it becomes necessary to understand what physical, economic, and social factors influence the farmer's acceptance of those practices.

It has been shown that within an area of similar soils, physical factors are likely to be of secondary importance in determining the kind and amount of soil conservation established.[1] This paper concerns itself with some economic factors that may influence a farmer to accept recommended soil conservation practices and win his attitude toward soil conservation. It is hoped that the findings of this study will contribute to a better understanding of the reasons which motivate the individual farmer to accept or to reject specific soil conservation practices.

A sample of 188 farm plans confined to the Honeoye-Lima soil association was studied. It included all the farms that had signed a cooperative agreement with the Soil Conservation district during the years 1946, 1947 and 1948. Data were compiled from the year when the agreement was signed until the end of 1952.

The area from which this sample was drawn in essentially a cash crop area and represents one of the most important agricultural areas of New York State. The Soil Conservation districts that supplied the data in the sample area were Cayuga, Ontario and Livingston. In addition to this sample of 188 farm plans, which will be referred to as the large sample, a subsample of 30 farms from the Cayuga district was used for intensive study. Half of them belonged to the high conservation group and the other half to the low conservation group. They were drawn out of a population of 43 and 35, respectively, by using Snedecor's[2] table of random numbers.

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* Contribution from the Department of Agronomy, New York State College of Agriculture, Cornell University, Ithaca, N.Y., as agronomy paper No. 435.

[1] Prundeanu, Julian, "A Study of Possible Reasons for the Differential Acceptance of Soil Conservation Practices in Selected Areas of Honeoye-Lima Soil Association." Unpublished. Ph.D. thesis, Cornell University, 1955.

[2] Snedecor, W. B., *Statistical Methods*, Ames: The Iowa State College Press, 1953.

In both cases the data on soil conservation practices were obtained from the district file of the farm under study. There was a difference, however, in the way the economic data were obtained. In the case of the large sample, the data were obtained from the district files, while economic data for the Cayuga subsample were obtained as a result of a personal interview with the farmers.

Methods

Two different approaches were utilized in analyzing the data. One consisted in relating the individual soil conservation practices (there were 20 such practices considered) to single economic factors.[3]

The methods used for this purpose were: (a) the correlation coefficient r,[4] and (b) Pearson's mean square contingency.[5]

In computing the correlation coefficient, X represented the economic factors expressed as actual amount (number of acres, number of cattle, etc.), while Y represented the amount of soil conservation practices established, expressed as percentage of the total amount planned by the Soil Conservation technician. The kind and amount of soil conservation practices planned should be understood as practices recommended by the Soil Conservation Service technician. It does not necessarily mean that the farmer had agreed to establish these practices.

The other statistic, Pearson's mean square contingency, was computed as $\frac{\text{chi square}}{n\ (q\text{-}1)}$ in which n is the total number of items and q the number of rows or columns, whichever the smaller. Pearson's mean square contingency had the advantage over the chi square because it gives information about the *degree* of dependence and because it does not require the restriction of minimum expected frequency.[6]

For the second approach, the farmers in each of the three samples (Cayuga, Ontario, and Livingston) were divided in two groups, one high conservation group and one low conservation group.

The high conservation group consisted of the farmers which had completed *more* than half of the soil conservation practices.[7] The farmers who *had* completed *less* than half of the recommended practices belonged to the low group. Not the amount of the individual practice established but the over-all accomplishment of the respective farmer was considered this time.

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[3] The economic factors considered were: total PMA payments; number of cattle; total acreage; cropland; land in pasture; woodland.

[4] Snedecor, W. G., *Statistical methods, op. cit*

[5] Cramér, Harald, *Mathematical methods of Statistics*, Princeton University Press, 1946.

[6] *Ibid.*

[7] A practice was considered completed when established 75 per cent or more.

It is realized that this grouping appears to destroy information. After much discussion with farmers, soil conservation planners, and others, the "high" and "low" conservation groupings were decided upon. This was necessary because no common index of completion of practices has been arrived at in order to treat the dependent variable as a continuous variable. While it is true that spurious statistical significance could occur by this grouping, an even greater error could be introduced by selecting some faulty index of completion. It was not the purpose of this study to develop an index of accomplishment. Such a methodological question must await further developments. More research, more empirical results are needed before such an index could be developed.

A t test was run to find out if there were any significant differences between the two groups with regard to the various economic factors and the establishment of individual conservation practices.

In the Cayuga subsample, in addition to the t test for the economic data, the tables of the binomial probability distribtion were used for analyzing the data on farmers' attitudes.

Results and Discussion

The results of this study are presented according to the method of investigation used.

Correlation Coefficient and Pearson's Mean Square Contingency.

Of a total of 82 correlation coefficients computed in Ontario,[8] only six showed significance, with two of them being highly significant.

Pearson's mean square contingency was computed for each of the three individual samples (Ontario, Cayuga, and Livingston). Of a grand total

TABLE 1. CORRELATION COEFFICIENTS SHOWING SIGNIFICANCE (ONTARIO DATA)

Economic Factor	Soil Conservation Practice	n[a]	r[b]
Cattle	Contour farming	41	0.59**
Cattle	Pasture seeding	8	−0.66*
Cattle	Permanent fences	18	−0.53*
Size of planned area[c]	Tile drainage	37	−0.33*
Size of planned area	Pasture seeding	8	0.94**
Permanent pasture	Pasture improvement	36	−0.33*

[a] Total number of paired items.
[b] Correlation coefficient.
[c] Planned area refers to the area for which a farm conservation plan was worked out by the Soil Conservation technician.
* Significant at 5 per cent level.
** Significant at 1 per cent level.

[8] The correlation coefficient was computed only for Ontario sample.

TABLE 2. MEAN SQUARE CONTINGENCY 0.50 AND OVER

Economic Factors	Soil Conservation Practice	Cayuga Sample		Livingston Sample	
		PMSqC[a]	n[b]	PMSqC[a]	n[b]
Permanent pasture	Pasture seeding	0.89	16		
Cattle	Open drainage	0.51	9		
Size of planned area	Permanent fences			0.68	10
Cattle	Strip cropping			0.66	12

[a] Pearson's mean square contingency.
[b] Total number of items.

of 299 Pearson's mean square contingency, only four had values 0.50 and over, two in Cayuga, two in Livingston and none in Ontario.

The results obtained using both the correlation coefficient and Pearson's mean square contingency lead to the conclusion that little relationship, if any, could be found between single economic factors and the amount of individual soil conservation practices established by the farmer in the area under study.

On the other hand, the amount of soil conservation practices established

TABLE 3. RELATION BETWEEN FARMERS' AGREEMENT TO VARIOUS SOIL CONSERVATION PRACTICES AND AMOUNT ESTABLISHED (ONTARIO SAMPLE)

Soil Conservation Practices		S.C. Practices Planned	Agreed	Established	Establ. Expr. as Per Cent of Agreed	Establ. Expr. as Per Cent of Total Planned
Tile Drainage	L.F.	99,660	97,310	103,700	107	104
Est. Perennial Hay	Acres	279	213	214	100	76.7
Tree Planting	Acres	7	7	8	114	114
Woodland Management	Acres	342	168	179	107	52.3
Wildl. Area Improv.	Acres	101	91	92	101	91.1
Woodland Protection	Acres	300	226	221	97.8	73.7
Stream Chan. Improv.	L.F.	3,600	3,200	3,100	96.9	86.1
Pasture Management	Acres	542	271	259	95.5	47.8
Farm Drainage	Acres	1,170	1,101	974	88.5	83.2
Structures	#	23	16	14	87.5	60.9
Open Drainage	L.F.	51,810	40,380	35,400	79.4	68.3
Outlets & Farm Water Courses	L.F.	42,590	37,460	29,500	78.8	69.3
Pasture Improvement	Acres	582	384	287	74.8	49.3
Contour Farming	Acres	2,022	1,289	877	68.4	43.4
Farm Ponds	#	13	13	8	61.5	61.5
Permanent Fences	Rods	1,700	1,000	570	57.0	33.5
Clearing Land	Acres	272	182	83	45.9	30.5
Strip Cropping	Acres	1,451	553	226	40.9	15.6
Crop Rotation	Acres	3,863	2,788	1,082	38.9	28.0
Cover Crop	Acres	3,539	2,138	759	35.5	21.4
Seeding Pasture	Acres	104	94	30	31.9	28.8
Field Diversions	L.F.	4,750	0	0	0	0

seems to depend to a great extent on the agreement of the farmer with the recommendation of the Soil Conservation Service technician.[9] This was shown very clearly by the Ontario data which included both the recommended and the agreed practices. Thus, there were 13 practices established 70 per cent and more when only the practices the farmer agreed upon were taken into consideration as against 7 practices established to the same extent, i.e. 70 per cent or more, of the recommended practices which included both agreed upon and non-agreed. Of these four times as many were established 95 per cent and more (8 and 2 practices respectively) when only the practices the farmers agreed upon were considered.

High Conservation Group vs. Low Conservation Group. (t test)

The t test was run for the pooled data (Cayuga, Ontario and Livingston data) as well as for the Cayuga subsample.

TABLE 4. SUMMARIZED ECONOMIC DATA AND T VALUES (CAYUGA, ONTARIO, AND LIVINGSTON DATA)

Economic Factor	High Conservation Group $\bar{x}_1$	Low Conservation Group $\bar{x}_2$	d.f.	t Values
Total Acreage	122.3	147.7	186	2.045*
Cropland	89.0	99.9	179	1.280
Land in permanent pasture	19.2	21.7	144	.765
Land in woods	6.8	16.7	100	3.855**
Cattle (No.)	13.7	14.1	107	.183
Total PMA payments[a] ($)	483	316	127	2.603**

* Significant at 5 per cent level.
** Significant at 1 per cent level.
[a] PMA data represent average figures for a four year period and include only the farmers who actually received PMA payments.

The farmers of the high conservation group had smaller total farm acreage, less cropland, less land in permanent pasture, and much less land in woods than the farmers of the low group. This meant that there was a greater need for conservation to start with for the low group than for the high group. On the other hand, the farmers of the high group received significantly more PMA payments for the establishment of soil conservation practices than the farmers of the low group.

An interesting picture was obtained when the t test was run for individual soil conservation practices in order to find out if there were significant differences between the two groups in this respect. Two different t tests were made: one for the actual amount of soil conservation

[9] Zwerman, Paul J. and Julian Prundeanu, "Obstacles to Soil Conservation," *Journal of Soil and Water Conservation*, Vol. 11, No. 3, May 1956.

established, and another for the amount of soil conservation practices established expressed as a percentage of total planned. In Table 5 the results of the two t tests are given with the individual soil conservation listed in increasing order of the percentage of establishment for the high conservation group (from 46.8 per cent for strip cropping to 90.0 per cent for farm ponds).

TABLE 5. POOLED CAYUGA, ONTARIO, AND LIVINGSTON DATA

Soil Conservation Practice	d.f.	Actual Amount Established			Amount Established Expressed as Per Cent of Planned		
		High group $\bar{x}_1$	Low group $\bar{x}_2$	$t_{\bar{x}_1 \bar{x}_2}$	High group $\bar{x}_{11}$	Low group $\bar{x}_{22}$	$t_{\bar{x}_{11} \bar{x}_{22}}$
Strip cropping (acres)	53	23.9	8.2	4.242**	46.8	17.1	4.371**
Woodland management (acres)	32	7.4	4.5	1.356	53.9	26.2	2.516*
Wildlife area improvement (acres)	21	4.0	4.2	.043	57.9	47.8	.612
Field diversions (feet)	12	1140	586	1.094	58.0	20.0	2.536*
Tree planting (acres)	20	1.9	1.4	.750	63.6	51.5	0.705
Contour farming (acres)	109	29.8	19.0	2.870**	65.0	33.6	5.134**
Permanent fences (rods)	28	71.0	60.0	.282	66.5	28.7	3.347**
Rotation (acres)	105	47.9	29.7	3.175**	70.1	33.9	6.147**
Pasture seeding (acres)	18	12.1	5.7	1.457	83.9	37.1	3.090**
Open drainage (feet)	58	2030	990	3.373**	84.0	47.3	3.972**
Pasture management (acres)	87	23.1	12.9	3.041**	84.3	45.5	5.566**
Establishing perennial hay (acres)	65	13.7	6.9	1.974	85.0	55.6	3.536**
Clearing land (acres)	88	7.4	4.7	1.585	85.2	52.7	2.389*
Outlets and farm watercourses (feet)	106	198	148	1.718	85.7	62.1	3.722**
Pasture improvement (acres)	110	21.6	12.7	2.846**	86.6	51.4	5.823**
Tile drainage (feet)	96	2770	2110	1.482	87.2	62.3	3.813**
Farm drainage (acres)	135	23.7	16.8	2.136*	88.9	62.7	5.156**
Woodland protection (acres)	47	11.6	12.7	.288	89.2	58.5	3.124**
Structures (No.)	63	1.9	1.0	3.147**	89.6	65.0	3.065**
Ponds (No.)	27	.95	.92	.174	90.0	73.0	1.392

* Significant at 5 per cent level.
** Significant at 1 per cent level.

The farmers of the high conservation group have established a higher amount in the case of 19 out of the 20 practices considered. Of these 19 practices, the amount established by the high group was significantly higher for eight practices, including significance at 1 per cent level for seven of them.

The differences were still bigger when the amount established was expressed as a percentage of the amount planned. For every one of the 20 soil conservation practices a greater percentage was established by the high conservation group. For no less than 17 practices, significant differences have been found between the two groups, 15 of which were significant at 1 per cent level of significance.

Taking another look at Table 5, one can roughly group the practices established to a larger percentage in two categories: (a) practices related directly to land improvement (tile drainage, outlets and farm watercourses, structures, clearing land, ponds), and (b) practices related to grassland (pasture seeding, pasture improvement, pasture management, establishment of perennial hay). To these should be added woodland protection. Among the practices established to a much lower percentage

belong strip cropping, contour farming, field diversions, wildlife area improvement, and tree planting.

The practices established to a larger extent were not necessarily the least expensive to install. They required, however, comparatively little maintenance and represented less inconvenience for the farming operations than the practices established to a lesser extent.[10] Moreover, they belonged to the practices to which the farmer agreed. They also represented practices for which substantial federal or, in some cases, state aid was made available in order to promote their use.

Discussion of the Cayuga Subsample

A t test was also computed for Cayuga subsample consisting of a total of 30 farmers divided equally between the high conservation group and

TABLE 6. SUMMARIZED ECONOMIC DATA AND T VALUES: SUBSAMPLE CAYUGA (30 FARMERS)

Economic Factor	High Conservation Group $\bar{x}_1$	Low Conservation Group $\bar{x}_2$	d.f.	t Values
Total acreage (acres)	197	296	28	2.245*
Cropland (acres)	153	215	28	1.907†
Permanent pasture (acres)	9	18	28	0.945
Woodland (acres)	8	37	28	2.704*
Cattle (No.)	10	20	28	1.971†
Total PMA payments ($)	589	322	21	2.068*
Total hens (No.)	500	140	28	1.930†
P.M.U.W.[a] (No.)	411	536	28	1.170
Total capital investment ($)	41,500	40,400	28	0.121
Land and buildings ($)	24,500	21,200	28	0.425
Livestock ($)	5,500	8,000	28	1.018
Equipment ($)	11,500	11,200	28	0.121

* Significant at 5 per cent level.
† Significant at 10 per cent level.
[a] Productive man work units.

the low conservation group. This time a few new features were introduced. Additional economic factors (total capital investment, value of land and buildings, value of livestock, value of equipment and productive man work units) were tested. Moreover, a total of 18 questions of a more general nature, that could have direct or indirect bearing on the kind and amount of soil conservation established, were considered. These questions included: (a) the farmer's idea about what soil conservation is; (b) how important he thought soil conservation was to him on his farm; (c) what place it occupied in his future plans with regard to the overall management of the farm; (d) his objections to specific soil conservation

[10] Zwerman, Paul J. and Julian Prundeanu, "Obstacles to Soil Conservation," *op. cit.*

practices; (e) his education; and (f) his participation in professional associations.

The farmers of the high conservation group in the Cayuga subsample compared with the farmers of the low group as follows:

(a) They operated smaller farms; however, their farms were much larger than the average for the area.
(b) They had smaller amounts of land in woods and permanent pasture.
(c) They had fewer cows but more hens.
(d) The value of their livestock was lower while the value of their land and buildings was higher.
(e) A larger number of farmers operated their farms on father-son partnership.

Note that relatively little difference was found between the two groups with regard to the total capital investment and the value of the equipment.

Farmers' Attitude to Questions Thought to Have a Bearing on Acceptance of Soil Conservation Practices.

In general, most of the farmers interviewed had a fair idea of what soil conservation is. For the purpose of this presentation, soil conservation was considered as the sum total of practices recommended by the Soil Conservation planner in order to minimize the hazards of soil erosion and to improve the productivity of the land. The farmer's knowledge of soil conservation was evaluated on the basis of the farmer's understanding of the reasons behind the recommendations of the planner.

With regard to the importance of soil conservation, a much higher number of the high conservation group considered soil conservation as being very important, and the stress here lies on "very." Practically no difference was found between the farmers of the two groups with respect to their membership in professional associations (mainly Farm Bureau) and their education. Their over-all farm management plans included new buildings, improving livestock, and buying new equipment in that order. Only after all these were taken care of did the farmer turn his attention and efforts to establishing practices meant to maintain or improve the productivity of his land. When a theoretical alternative of having extra money available to the amount of 10 to 20 per cent of their total capital investment was introduced, most of the farmers would use some of this money for soil conservation practices. This substantiates what had been said previously with regard to the place soil conservation occupies among the other farm management practices. At the same time

it stresses the importance of payments as incentive for the farmers to establish soil conservation practices.

The specific soil conservation practices that the farmers objected to most were contour farming and cropland terraces. Moreover, the need for them was not recognized and the inconvenience which they represent to the farming operations was generally stressed. On the other hand, there was general agreement among the farmers of both groups about the usefulness of tile drainage.

The farmers generally appreciated the technical assistance and advice given to them by the Soil Conservation technicians. However, they would rather do without these services or they would make use of them to a much lesser extent if they had to pay for them as a commercial service. The farmers felt they were entitled to these services as they were entitled to the services of any other agency supported by public funds.

With regard to the incentive payments for establishing soil conservation practices, no one complained about receiving them and they were generally considered welcome, although there was not a general agreement about the need for them. The disagreement concerning their usefulness was, in almost all cases, due to the confusion between the payments for the establishing of soil conservation practices with the price support program.

Questions Thought to Have a Bearing on Acceptance of Soil Conservation Practices and Farmers' Answers

TABLE 7. WHAT IS SOIL CONSERVATION?

Degree of Understanding	Number of Farmers	
	High Group	Low Group
High	9	10
Medium	5	3
Low	1	2

TABLE 8. IMPORTANCE OF SOIL CONSERVATION

	Number of Farmers	
	High Group	Low Group
Very important	10	6
Fairly important	3	7
Not important	2	2

TABLE 9. FARMERS' FUTURE PLANS

	Number of Farmers	
	High Group	Low Group
No plans	1	3
Building improvement	4	8
Increasing livestock	1	8
Fixing the land*	3	2

* Means primarily use of soil conservation practices.

TABLE 10. FARMERS' FUTURE PLANS WHEN AN EXTRA 10 TO 20 PER CENT OF TOTAL CAPITAL INVESTMENT AVAILABLE

	Number of Farmers	
	High Group	Low Group
Buildings	9	12
Buying Equipment	6	6
Buying Livestock	1	2
Buying Land	2	2
Fixing the land	10	12

TABLE 11. MEMBER OF FARM ORGANIZATIONS

Farm Organization	Number of Farmers	
	High Group	Low Group
None	1	0
Farm bureau	14	14
Grange	3	2
Others	3	7

TABLE 12 SCHOOLS ATTENDED

	Number of Farmers	
	High Group	Low Group
Grammar school	2	1
High school	9	8
College	4	6

Farmers' Attitude Regarding Some Individual Soil Conservation Practices

TABLE 13. CONTOUR STRIP CROPPING

Answer	Number of Farmers	
	High Group	Low Group
Not needed	3	5
Fields would be too small	6	3
Requires relocation of fences	2	7
Difficult to pasture aftermath	1	6
Waste of time, money, and fuel	0	2

TABLE 14. CROPLAND TERRACES

Answer	Number of Farmers	
	High Group	Low Group
Would not fit this particular situation	8	6
Not enough slope	5	4
No opinion	3	1

TABLE 15. TILE DRAINAGE

Answer	Number of Farmers	
	High Group	Low Group
Too expensive	1	2
Lack of capital	3	8
Lack of outlets	4	1
No objections	3	6
Likes them	11	6

TABLE 16. OPEN DRAINAGE

Answer	Number of Farmers	
	High Group	Low Group
Waste of land	0	5
Maintenance problem	5	4
Cut up fields	3	2
Could not do without	9	2

Summary

Acceptance or nonacceptance of soil conservation practices by the farmer is a complex process in which the physical characteristics of the land, economic factors, as well as the attitude of the farmer *may* be involved. It has been shown that the physical characteristics of the land alone such as soil drainage, amount of erosion that has taken place, slope, and land use capability are not necessarily related to the kind and amount of soil conservation practices established by the farmer.

When individual soil conservation practices were tested against individual economic factors, little or no relationship was found by using both simple correlation (r) and Pearson's mean square contingency. When, however, the over-all accomplishment of the farmer was considered, a definite trend seemed apparent. Thus, the high conservation group has higher total acreage, more cropland, less land in woods, and received higher PMA payments. This was true for both the pooled data of Cayuga, Ontario, and Livingston soil conservation districts and for Cayuga subsample. The statistic used was t test.

It is important to note that the farmer's agreement to the practices recommended by the soil conservation technician seemed essential to the establishment of the respective practice. This was the case with both the high and low conservation group. The establishment of drainage and tree planting in the Ontario district represents a good illustration. By the same token, if the farmer considered soil conservation *very* important he generally had established many more soil conservation practices than those who were indifferent to soil conservation.

This study should be viewed as a pilot study intended to use present statistical methods to find out some of the reasons behind the decision of the individual farmer to accept certain soil conservation practices and to reject others. It seems that the t test used in conjunction with grouping the farmers according to their over-all accomplishments represents a step in the right direction. This, accompanied by the interview approach, helps to find some of the answers. Nevertheless, there are some definite limitations one should be aware of, among which the lack of an index of accomplishments with regard to soil conservation practices is by far the most important. It is hoped that future research will bring forth the needed material and the facts on which such an index may be based.

APPARENT RESULTS IN USING SURPLUS FOOD FOR FINANCING ECONOMIC DEVELOPMENT*

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DURING the past four crop years, movement of U. S. agricultural surpluses under Title I of Public Law 480 has become the principal means of disposing of farm surpluses abroad. Nearly 4 billion dollars worth of surpluses have been disposed of altogether in this way, and this has contributed materially to some decline in stocks still held by the Commodity Credit Corporation. An additional 2¼ billion dollars for such disposals over 1½ years ahead has just been authorized by Congress.

Title I of Public Law 480 authorizes sales of surplus commodities for payment in local currencies, with a major part of the local currency proceeds to be loaned back to the recipient countries to help finance their own economic development. An exploration by FAO of how such disposals could work indicated that they might under certain conditions lead to increased consumption in the recipient countries, thus aiding their economic development and helping move surpluses into consumption abroad, without harming markets for usual commercial producers in those countries or in other exporting countries.[1] In view of the importance of such operations, efforts to determine their effects in practice have been discussed for some time. This paper summarizes the results thus far available from such studies.

Since Public Law 480 was passed, agreements have been signed by the U. S. for disposals under Title I with a substantial number of countries. These included 616 million bushels of wheat (and flour) under all phases of Title I made during the four crop years 1954-55 through 1957-58.[2] Large quantities of wheat and other surplus products have been shipped to recipient countries. Among the agreements specifying economic development as a major objective, and reserving a major part of the foreign currency proceeds for loans for this purpose, five are especially important—those with India, Spain, Brazil, Pakistan, and Yugoslavia. (See Table 13.) The largest was the initial three year Indian agreement (360 million dollars), with two-thirds of the proceeds for such loans. The Brazilian agreement (180 million dollars) had over four-fifths of the proceeds

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* Based on paper presented at International Wheat Surplus Utilization Conference, Brookings, South Dakota, July 25, 1958.

[1] Uses of Agricultural Surpluses to Finance Economic Development in Underdeveloped Countries, A Pilot Study in India, FAO Commodity Policy Series No. 6, 1955, 65 pp.

[2] From data compiled by Grain and Feed Division, Foreign Agricultural Service, USDA "1957-58" means the crop year, mid '57 to mid '58.

for loans. The Pakistan agreements (186 million dollars), however, had less than one-third of the proceeds for loans, and almost half for military procurement. The series of agreements with Yugoslavia totalled 276 million, but only the last two agreements, for 171 million dollars, had a substantial proportion (three-quarters) for loans to the government.[3] The Spanish agreement had a little over half for loans.

TABLE 1. PLANNED USES OF FOREIGN CURRENCY UNDER MAJOR TITLE 1, PUBLIC LAW 480

Agreements Signed 1 July 1954–30 June 1958: Total and Loans to Selected Countries

Recipient Country	Total Amount Programmed (Market Value, including ocean transportation)	Planned Use of Foreign Currency Proceeds as Loans to Recipient Governments
	(in million dollars)	
India	419.4	269.2
Spain	283.1	157.5
Yugoslavia	294.6	135.3
Pakistan	186.1	54.4
Brazil	179.9	149.2
Turkey	162.6	75.7
Italy	152.9	100.5
Japan	150.8	108.9
Poland	138.0	—
Korea	132.0	—
Indonesia	96.7	77.4

Source: Eighth Semiannual Report on Activities Carried on under Public Law 480.

Smaller but substantial Title I agreements were signed with 35 other countries for amounts of 40 million dollars or more, including Austria, Burma, Chile, Greece, Indonesia, Israel, Italy, Japan, Korea, Poland, Turkey and United Kingdom. In most of these latter agreements half and frequently two-thirds of the local currency proceeds were planned for loans to foreign governments. Exceptions were the agreements with Korea, Poland, Turkey and United Kingdom, where the foreign currency went, in major part, for military procurement or for payment of U. S. obligations. Many smaller agreements with other underdeveloped countries, as for example 39 million to Columbia, 25 million to Peru, and 20 million to Egypt, had from half to three-quarters of the local currency proceeds scheduled for loans to governments.

Parallel, though smaller, agricultural disposal arrangements for grain have been entered into by Canada under the Colombo Plan commitments. Smaller dry skim milk contributions to the development of improved milk marketing facilities in India have been made by several countries

[3] Eighth semiannual report on activities carried on under Public Law 480, etc. January 1 through June 30, 1958. 85th Congress, 2d session, House of Rep., Public Doc. 431, Aug. 5, 1958.

under arrangements worked out through a subgroup of the Washington FAO Subcommittee on Surplus Disposal; similar proposals are pending final acceptance for Pakistan.

Only 40 per cent of the total funds set aside for local currency loans for economic development had been approved for expenditure for specific projects by mid-1958, and no doubt actual expenditures are lower still.[4] It is therefore too early to make any clear appraisal of the specific development projects financed from such local funds, or of the impact of these projects on the economy of the countries concerned. Deliveries under these agreements have thus run far ahead of drawings on these specific funds. The sale of these surplus products internally has, however, already withdrawn a part of the local currency from internal expenditure. In some cases these withdrawals may have reduced internal inflationary pressures and enabled the government of the recipient country to use deficit finncing to pay for a larger volume of economic development expenditures than would otherwise have been possible. They may thus have contributed to economic development even though the currency deposited with the U. S. has not been drawn upon.

India is an obvious case where this may have happened. India has had a serious inflationary pressure during recent years. Apparently the planned development programs exceed that country's capacity to finance them from current domestic savings or foreign loans. In addition, with improved income for India's farmers and some increase in real incomes per capita for the whole population, consumption or retention of foodstuffs on the farms has increased sharply, so that gradually increasing crop production has not been reflected in corresponding increased commercial marketings available for feeding the cities. In meeting this situation, India has imported large quantities of wheat commercially and has imported all of the wheat scheduled under the three year agreement ahead of schedule. In the calendar year 1956, it imported 672 thousand tons from other exporters in addition to 423 thousand tons from the U. S. In 1957, however, when U. S. imports rose to almost 2.7 million tons, imports from other exporters fell to 172 thousand tons.[5] However, rice imports in 1957 were twice as large as in 1956, so commercial imports of wheat might have declined that year even if concessional supplies of wheat had not been available. As shown by the detailed figures in Table 2, Indian wheat imports from other countries averaged nearly as much in 1956 and 1957 as during the three years preceding. The import situation in these earlier years, too, had been influenced by large supplies from the U. S. "wheat loan," obtained in the 1951 food crisis. (See Table 2).

[4] *Ibid.*, pp. 18, 37.

[5] Data from National Food Reserve Policies in Underdeveloped Countries, FAO Doc. CCP 58/14, 29 May, 1958, p. 40 (English ed.)

TABLE 2. IMPORTS OF CEREALS ON GOVERNMENT ACCOUNT INTO INDIA, 1950–57[a]

Source	1950	1951	1952	1953	1954	1955	1956	1957
	(thousand long tons)							
	Wheat and Flour (as wheat)							
U. S.	50	1,810	1,763	577	—	129	428[b]	2,674[e]
Other countries	1,357	1,205	748	1,107	197	306	672	172
Total	1,407	3,015	2,511	1,684	197	435	1,095	2,846
	Rice							
U. S.	—	—	—	—	—	—	—	194[d]
Other countries	353	749	722	175	603	265	325	542
Total	353	749	722	175	603	265	325[c]	736
	Other Grains							
U. S.	344	589	540	111	8	—	—	—
Other countries	21	372	91	33	—	—	—	—
Total	365	961	631	144	8	—	—	—

[a] Source: FAO, National Food Reserve Policies in Underdeveloped Countries, Rome, 1958, p. 40, mim. edition (English).
[b] Includes 278,000 tons under Public Law 665; balance, Public Law 480.
[c] Includes 199,000 tons under Public Law 665; balance, Public Law 480.
[d] Received under Public Law 480.
[e] Includes 5,000 tons received from Pakistan as repayment of loan.

Thus, the fragmentary data available on India gives no clear-cut picture of the effect of Public Law 480 shipments on economic development, or to what extent they have been matched by increased consumption within the country or have replaced supplies which might have come from other exporters. It is clear, however, that with the increasing shortage of foreign exchange, India probably could not have financed equally heavy importation of wheat by commercial purchases if the U. S. wheat had not been available on special terms—except by greatly reducing its other imports, including essential supplies for current production and equipment for maintenance and expansion of productive equipment. Intensive study of the actual happenings within the country during this period, as well as of the external dollar trade figures, would be necessary to give a more precise appraisal.

Readily available data for Pakistan are still more fragmentary. The Food Reserve study, from which the trade data for India were drawn, unfortunately does not give similar details for Pakistan. The widely separated halves of the country and the great variability of wheat and rice production in the western and eastern halves, respectively, make the necessary analysis still more complicated.

The only formal study published on the effect of food surpluses on economic development is for Japan. It was completed this spring

under the leadership of Dr. Ojala, head of the joint FAO/ECAFE Agriculture Division at Bangkok.[6] This report analyzes the distribution and the results obtained under successive U. S.-Japanese agreements for surplus food purchases in 1955 and 1956, covering the sale of 151 million dollars worth of surplus commodities (including ocean transportation), with 125 million dollars of the yen proceeds, or over three-quarters, to be reloaned to Japan for financing economic development projects. In addition, under the 1955 agreement, the U. S. agreed to provide 15 million dollars worth of surplus wheat, dried milk and cotton (at CCC costs) at a Title II grant, to expand children's welfare programs in Japan, with declining amounts in subsequent years. The cotton part of this grant was subsequently converted to wheat. The Title I agreements covered wheat, barley, rice, cotton, and tobacco.

The Japanese government based its purchases on estimates made by its food agency of the prospective demand and supply of each commodity during the projected period of disposal, its forecast of normal trade development for each commodity during that period, and the need of yen funds for additional development projects previously excluded from the government program of investments and loans. This process is described as follows:

> . . . an estimate is made of the demand for yen funds needed for economic development projects which have been wholly or partly excluded from the government programme of investments and loans. The amount of surplus commodities to be sought is thus finally decided after the import requirements are reconciled with the additional yen fund requirements, and the latter factor has been given greater weight in relation to the second Agreement than to the first.
>
> This adjustment seeks only to reconcile the import requirements in monetary terms with the additional yen fund requirements for development plus any yen proceeds from surplus commodity imports likely to be used by the United States. So far, the Japanese Government has not explicitly attempted to find a point of equilibrium at which the surplus commodities obtained are in line with the additional consumption of these commodities generated by the development schemes aided by local currency proceeds. However, the method of calculating total import requirements as described under (a), together with the above-mentioned reconciliation, seems to allow implicitly for the effects of development expenditure on consumption.
>
> The yen proceeds earmarked for economic development which were derived from surplus transactions accounted for 7.7 per cent and 6.8 per cent of the total financial resources available for government investments and loans in 1955/56 and 1956/57 respectively.[7]

The major additional projects on which the yen funds were used were on electric power, irrigation, agricultural and forestry land development,

[6] A Note on the Utilization of Agricultural Surpluses for Economic Development in Japan, U. N. & FAO Doc. E/CN.11/L.60, Bangkok, 1958, 46 pp.

[7] *Ibid.*

and a number of smaller projects, industrial, marketing facilities, etc. Up to September 30, 1957, 39 billion yen had been allocated to projects, and 33 billion spent, or about 83 per cent of the loan funds established under the first two Public Law 480 agreements.

An attempt was made to estimate the per cent of these project expenditures which would reappear in additional purchases of surplus goods, following the methods of the Indian Pilot study. With the relatively high level of per capita income in Japan, the income elasticity of demand for wheat is negative. Even when allowance was made for clothing based on surplus products, the per cent covered was materially lower than was estimated for India in the India Pilot study. While no figure was given in the report, the per cent of additional development expenditures reflected in increased purchases of surplus products is probably below 25 per cent in Japan, on this basis.

However, Japan does have major industrial resources which may not have been fully employed. Once essential food and cotton was provided, the Japanese may have been able to satisfy the other increased demands resulting from industrial development largely by expanded manufacturing and service industries. In addition, expenditures of the yen allocated for additional military housing in Japan and for Japanese goods for export to other countries also may have produced increased internal demands for surplus products.

In any event, wheat imports expanded sharply in Japan during the period surplus supplies were available under Mutual Security and Public Law 480 legislation. Excluding surplus commodities, commercial wheat imports for the three years 1954/55 through 1956/57 totalled 5.4 million tons, compared to 5.0 million for the preceding three years. Commercial imports from the U.S. totalled 2.1 million tons during the last three year period, as compared to 3.1 million during the three preceding years. (Note Table 3). In this case, then, the imports from suppliers other than the U. S. showed a substantial net gain over 50 per cent. However, the earlier imports had included substantial quantities of U. S. wheat imported under occupied area relief programs which may have depressed purchases from other countries, so even these comparisons are not definitive. Some other commodities, notably barley, did not show as favorable results for other suppliers; apparently the availability of more wheat may have reduced demands somewhat for barley.

In cotton, the surplus supplies were small compared to the total import, and the share of all U. S. imports (commercial and concessional) in total imports averaged smaller during the two years (1955 and 1956) that surpluses were available than during most preceding years, possibly due to

TABLE 3. IMPORTS OF SPECIFIC COMMODITIES INTO JAPAN FROM U. S. AND OTHER SOURCES, 1950/51–1956–57

Source	1950/51	1951/52	1952/53	1953/54	1954/55	1955/56	1956/57
Wheat, in thousand metric tons							
U. S.—Commercial	925[a]	999[a]	1,136	964	564	763	766[d]
Surplus	—	—	—	—	584[c]	372[b]	349[b,d]
All other countries	534	531	460	930	988	1,101	1,073
Total	1,459	1,530	1,596	1,894	2,136	2,236	2,188[d]
Barley in thousand metric tons							
U. S.—Commercial	251[a]	499[a]	368	175	103	301	289
Surplus	—	—	—	—	112[c]	57[b]	81[b]
All other countries	152	259	813	598	269	323	566
Total	403	758	1,181	773	484	681	936
Rice—milled equivalent—in thousand metric tons							
U. S.—Commercial	45[a]	102	242	318	175	155	4
Surplus	—	—	—	—	—	97[b]	—
All other countries	648	799	666	1,135	889	1,039	555
Total	693	901	908	1,453	1,064	1,291	559
Cotton, in millions of pounds							
U. S.—Commercial	627	393	464	324	445	225	418
Surplus	—	—	—	—	—	89[b]	52[b]
All other countries	156	444	479	743	634	658	855
Total	783	837	943	1,067	1,079	972	1,325

Source: FAO/ECAFE, A Note on the Utilization of Agricultural Surpluses for Economic Development in Japan, pp. 38–41.

[a] Including those imported under the Government and Relief in Occupied Areas (GAROIA) Funds.

[b] Surplus commodities bought under Title I of Public Law 480.

[c] Surplus commodities bought under Section 550 of the Mutual Security Act of 1951, as amended.

[d] Excludes grants of 92,874 tons.

price relations. (Tobacco disposals, also covered in the report, are not considered here.)

During the past six years, production of rice has risen in Japan, production of wheat has trended markedly downward, and production of barley has shown little trend. Apparent consumption of rice per capita has increased, while that of barley has declined, and wheat has declined recently. Wheat and barley consumption per capita are both far above prewar; however, rice has not regained prewar levels. Demand for wheat as bread has a marked positive income elasticity, suggesting that still further expansion of wheat and flour consumption may occur in the future with continued economic development and urbanization.

The report also gives many other details on considerations which led up to the surplus sale agreement, and on administrative procedures for

handling the commodites and the financial arrangements, which cannot be summarized here.

While the picture is confused by wheat-rice competition and by fluctuations in domestic production, the over-all results thus far in Japan appear favorable to the use of surplus products for economic development, with increased development expenditures, somewhat higher imports from other commercial suppliers, and no marked unfavorable effects on domestic producers. The shift from domestic production of wheat to rice also appears to have been in the direction of greater relative advantage.

Japan is not representative of most underdeveloped countries, having much more industrial development, higher levels per capita of income and production, greater dependence on foreign trade, and is probably better supplied with experienced administrators, technicians, scientists, and other skilled manpower. Also, it probably has less unemployed or underemployed labor than most underdeveloped countries, although this point was not investigated in the report. That similarly favorable results would be secured in less developed countries cannot, therefore, be taken for granted.

Proposals for Other Studies of Surplus Disposal

The FAO Washington Subcommittee on Surplus Disposal has given long study to the research that is needed to determine the effects in practice of surplus disposals, and has prepared two outlines for such research projects, covering, studies of surpluses used for economic development,[8] and of surpluses used for emergency/famine relief and special feeding programs.[9] These outlines provide close study of methods of operating the transactions, including administrative and financial techniques, as well as of the previous situation, the economic effects, and the effects on international trade and on subsequent economic conditions. In both types, detailed investigation would be needed in the recipient country; for best results, concurrent observations of market reactions and behaviour during the time the surpluses were being received and distributed would be needed. Since such studies are beyond the resources of the existing FAO staff, efforts are being made to interest others in the problem, and to secure outside resources with which to conduct additional studies, either by FAO or by other agencies. In the meantime, as opportunity develops, it is hoped that additional reconnaissance studies similar

[8] Report of the Working Group to Expand Pilot Research Study Outline (Use of Agricultural Surpluses in Economic Development), FAO, Doc. CCP/CSD/58/10, 7 March, 1958.

[9] Report of the Working Group to Expand Pilot Research Study Outline (Use of Agric. Surpluses for Emergency/Famine Relief & Special Feeding Programs), FAO Doc. CCP/CSD/58/23, Rev., 9 June, 1958.

to the one for Japan can be undertaken by FAO staff, probably as part of the joint staff operations in cooperation with the several U N regional economic commissions.

Conclusions

While the evidence thus far shows no conclusive proof that the disposal of surpluses for economic development can help recipient countries, and can do so without harming other exporters of the products involved, neither does it prove the contrary. Rather, it does suggest that under favorable conditions and good administration in the recipient countries, quite good results may be secured in both respects. To what extent other surplus disposal agreements have been equally well conceived and operated, only further study can tell.

NOTES

OUTPUT-INPUT RELATIONSHIPS REVISITED

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IN THE MAY issue of the *Journal of Farm Economics,* Earl O. Heady[1] discussed one set of relationships between output and input in agriculture over time. His paper was mainly in response to my treatment in "Reflections on Agricultural Production, Output and Supply."[2] I welcome this opportunity to revisit these particular issues.

Two points should be made at the outset. I had expressed the view that economists would like to know where the large growth in output relative to the small increase in conventional input has been coming from. Heady thinks this kind of a development is not hard to explain and neatly calls it my "mystery yet unsolved." But the "mystery" remains because his paper concentrates on quite another issue, namely: *if* the unexplained growth were to come from technical improvements, it would cause agricultural output to increase relative to input. Of course it would, and no one would disagree, but these relationships do not solve the "mystery," because there are other plausible explanations that also can cause agricultural output to increase proportionally more than input.[3]

The other point has to do with the analytical role of an output-input concept of unity. Heady was puzzled, for he asks ". . . ideal for what?" He appears to think of it, first, as a policy directive to be used to keep the process of production over time employing inputs at some constant ratio to output. This certainly is not its purpose. I, too, am not against economic growth. He then examines it in terms of his model and notes that there would be only two general cases under which the output-input ratio would remain constant (page 403). This means, as I interpret his analysis, that if one were to make technical improvements *the* explanatory variable, and if one were to treat technical improvements as a *free* good, then his inference would follow. But, as I have noted, there are also other ex-

* Zvi Griliches criticized this draft. I benefited.

[1] See, "Output in Relation to Input for the Agricultural Industry," *Journal of Farm Economics,* Vol. 40, May, 1958, pp. 393-405.

[2] In the *Journal of Farm Economics,* Vol. 38, August, 1956, pp. 748-762.

[3] Nor did I imply in my paper that technical improvements do not play a role in this kind of economic growth; on the contrary, I placed a good deal of emphasis on them, perhaps too much as Glenn L. Johnson has argued. See, Glenn L. Johnson, "Supply Function—Some Facts and Notions," appearing in *Agricultural Adjustment Problems in a Growing Economy,* Iowa State College Press, Ames: Iowa, 1958, edited by Earl O. Heady, Howard G. Diesslin, Harald R. Jensen, and Glenn L. Johnson.

planations, and technical improvements are not manna from heaven. They assuredly are the product of inputs that require resources as legislators, private donors, and corporation executives well know. Heady is of the belief that "Society would gain more if technical change . . ." could be made to turn this ratio in favor of output. I also believe this to be true. Suppose it is true. Technical improvements in agriculture, nevertheless, represent inputs, and these particular inputs should not be left out in explaining increases in agricultural output of a country. Moreover, it is high time that good, rigorous, production economics be employed to determine what these technical improvements cost and earn.

To return to the purpose of keeping before one a concept of output to input at unity. It is not a policy directive but an analytical device. I said, "The analytical task . . . is to re-establish a strong and satisfactory linkage between input and output over time." The closer we come to a one-to-one relationship in an analysis of the "factors" causing growth in output, ". . . the more complete would be our (economic) explanation." In this context, a gap between them may be viewed as a measure of our ignorance (more on this later). There also is the fact that in national income and resource accounting, income is equal to the resources employed at factor costs. There is no gap; there is no residual. The weights that the economy assigns give in fact a one-to-one relationship.

In the case of agriculture, suppose output were to increase 20 per cent between two dates, and conventional inputs were to increase 10 per cent; and, one were to find that increases in human capital contributed five percentage points to the increase in output and technical improvements contributed another five percentage points. Thus, there would be a one-to-one accounting, and the stage would be set to determine whether the rates of return on the resources employed to produce the extra human capital and the technical improvements were high, low, or approximately the same as the rate of return on conventional inputs. I do not want to take increases in human capital and technical improvements as given, or as "outside" variables, but I would want to treat them as part of "production" that also is determined by private and public allocative decisions. Accordingly, there is always the question: are we addressing ourselves to the same problem? The problem that I want to keep in focus is economic growth, ultimately increases in national income. The private accounts of farmers, important as they are, are not sufficient to give us a true measure of national costs and returns of all of the "inputs" employed in agriculture.

So much then for the present on these two preliminary points. My purpose, as I proceed, will be two-fold:

1. To discuss the first of the above issues somewhat more fully and to

indicate seven plausible explanations for output and input estimates that diverge.

2. To present some further reflections on the problem at hand.

A Number of Plausible Explanations

It should be said that Heady has done a great deal of pioneer work in developing ways and means of using production functions and related tools in agricultural research; and thus he speaks with authority on the role of such tools. His paper is especially helpful, because in it he puts clearly his conception of the role of these tools. His approach to the problem at hand, i, e., the problem presented to us by estimates of agricultural output that increase at a higher rate than do the estimates of agricultural inputs, consists of two parts: (1) he would "include industrial resources which serve *indirectly* (italics mine) as factors to agriculture"[4] (on which there should be no disagreement if they were not taken into account *directly),* and he would subdivide inputs into many more categories in analyzing agricultural production.[5] But this subdivision has its costs, and how far one would go in this direction would depend on some notion of the additional analytical returns obtained, set off against the additional costs of doing it. (2) He would then rely on "technical improvements" which he transforms into a "rate of increase in resource productivity" (see pages 400-1) as the explanatory variable. From a careful reading of the development of formulas (1) through (20), pages 398-402, it would appear that these technical improvements are treated as an *ad hoc* variable, that is, in a way so that changes in this variable might fit any and all output minus input residuals that emerge over time.[6]

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[4] Under the section, *Nonfarm Inputs,* page 395, Heady would treat part of the materials used by the steel industry to produce farm tractors as one of these industrial resources that serves *indirectly* as a factor to agriculture, and add this part to the input, now at hand, that measures farm tractors. But, inasmuch as these materials are taken into account *directly* in measuring farm tractors as a farm input, it would result in double counting. The same would be true for the other examples that he cites, whether they be fuels, fertilizers, or hybrid seed corn not produced by farmers but used in farming as inputs. Nevertheless, there may not be "a complete accounting of inputs" acquired from the industrial sector because of the way improvements in the quality of these inputs are measured or because particular new inputs are, in substance, carriers of a new technique.

[5] *Ibid.,* pp. 395-6. ". . . the production process is not adequately represented by a production function in which there are only three factors of production, capital, labor, and land." This comment is directed against the classical tripartite classification which I used for convenience of exposition. Eight sets of inputs were used in deriving the input estimates that appear in Table I of my paper. Heady's observation that ". . . there are hundreds of resources . . ." is, as he says, obviously true. But this does not tell one how many it "pays" to use or the maximum number that he has found best in actual studies of farms.

[6] Heady takes account of changes in demand, and in this, he would use a demand

The core of Heady's paper, accordingly, is devoted to the task of showing that if these are new techniques, it is possible to represent a production function as changing over time, and to show that such changes in a production function can account for increases in output relative to inputs over time. Solow[7] has done this with real estimates of income and resources for the United States between 1909 and 1949. That it is possible to do this, as already noted, I do not doubt; quite the contrary, it is all too convenient a way, so it would seem to me, of disposing of the rate of growth in output that is in excess of the rate of increase in input. It would be simpler and more straightforward merely to call it "favorable developments in the economy" or "gains in resource productivity," as Kendrick[8] has done, and let it go at that. My concern, however, is that this kind of analytical convenience, in effect, places much , or even most, of the causes of economic growth outside of economics, as one might treat weather;[9] and yet this approach has become the fashion on the part of many economists in studying economic growth. To treat these divergencies in output relative to input this way, is truly a measure of our ignorance.[10]

There can be no question that the concept of a production function is a major analytical tool in studying production. It has become more than a blackboard device for classroom instruction, or merely a way of thinking about what happens in production. It has been formulated

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variable that presumably would be firmly based on its price elasticity and on the effects of changes in income and in population upon demand. The demand, therefore, would not be treated as if it were an *ad hoc* variable. On the contrary, it can be specified, identified, and estimated independently. It is not of the nature of a residual in the analysis. Then, too, as I argued in my paper of August, 1956, the observed aggregate demand, fortunately, is made up of fairly stable values.

[7] Solow, Robert, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39, August, 1957, pages 312-20. He reports that his measured shifts of an aggregate production function netted out to be approximately neutral; that is, the shifts were pure scale changes, leaving marginal rates of substitution between capital and labor unchanged at given capital-labor ratios.

[8] Kendrick, John W., *Productivity Trends: Capital and Labor*, Occasional Paper 53, National Bureau of Economic Research, New York, 1956.

[9] In my, *The Economic Organization of Agriculture*, New York: McGraw-Hill, 1953, I also attributed the rise in output per unit of input mainly to new techniques of production, but I went on to discuss the "production and distribution" of such new techniques in agriculture. My treatment, nevertheless, was only exploratory and, as such, very preliminary.

[10] Moses Abramovitz makes this point in his *Resources and Output Trends in The United States Since 1870*, Occasional Paper 52, NBER, 1956, page 11, in commenting on his findings that national net product rose at a rate of 3.5 per cent and that of resources at only 1.7 per cent per year. He wrote, "This result is surprising in the lopsided importance which it appears to give to productivity increases, and it should be, in a sense, sobering, if not discouraging, to students of economic growth. Since we know little about the causes of productivity increases, the indicated importance of this element may be taken to be some sort of a measure of our ignorance about the causes of economic growth. . . ."

rigorously as a part of economic theory, it has been made manageable for empirical research, and it has been coupled with statistical inference in going to data drawn from real production behavior.[11] There are many circumstances when it is appropriate to analyze production in agriculture, and in other sectors, on the assumption that the underlying production function remains essentially invariant. I was mindful of these circumstances and referred to them with some care in my paper,[12] and in doing so, called attention to the excellent review by Glenn L. Johnson, "Results from Production Economics Analysis."[13]

Let me, now, restate the problem. There are estimates that show that the increase in agricultural output, between two dates, is substantially larger than the proportionate increase in agricultural input. Economists would like to obtain meaningful explanations. It is not always easy, however, to define "meaningful" in a context such as this. Meaningful by what standards? I would say by the test that it works analytically and that it is relevant. The latter implies that it is in some sense useful. In the case of the problem at hand, one feels intuitively that some important productive components have been added to agricultural inputs, as these inputs are conventionally conceived and treated, and that the rates of return on these "new" components may be relatively large. It would be useful to know whether there are any such new components, and, if so, what they contribute to production, and what each costs and earns. It would be useful to know this because it would permit evaluation of private and public allocative "decisions" with a view of better using and augmenting resources, including the new productive components.[14]

The basic difficulty is that there are a number of plausible explanations that could account for output and input estimates that diverge. Seven come readily to mind: (1) the increase in output has been overestimated; (2) the increase in input has been underestimated; (3) scale has become more favorable; (4) risk and uncertainty confronting farmers has been reduced; (5) disequilibria, represented by too many resources in agriculture, have been reduced; (6) something called "weather" has improved; and (7) transformation relationships between inputs and outputs not covered by

[11] Noteably, in the work of agricultural economists, Heady's book, *Economics of Agricultural Production and Resource Use,* Prentice-Hall, New York, 1952, bears testimony on the progress that has been made in these directions.

[12] See p. 756 and especially footnote 12 of my paper.

[13] It appears in the *Journal of Farm Economics,* Vol. 37, May, 1955.

[14] We also have many insights that indicate that new techniques of production have been contributing much to growth in output. Here, too, we want to know how much they contribute, what the value of this contribution is, what it costs, on public and private accounts, to discover the new techniques along lines of Zvi Griliches' study, "Research Costs and Social Returns: Hybrid Corn with Comparisons," *Journal of Political Economy,* (forthcoming).

(3), (4), (5), and (6) have improved. Moreover, it is possible for each of these to have taken the opposite course over time, or to have remained invariant. And, then, there are all the possible combinations. (Let no one underrate the nest of problems, some that are quite insolvable, that arise as one turns to index numbers as one must in this kind of an analysis. A moment of reflection should suffice to see that each of the changes from (3) through (7) raises ugly index number issues.)

Further Reflections on This Problem

It would be a serious mistake to attribute all of the divergencies between the *estimates* of agricultural output and input to technical improvements. There are a number a major of major conceptual and measurement problems inherent in these estimates. There are ommissions, duplications, and weak imputations. The concept of capital is far from satisfactory. That of quality and changes in it is no better. Man-hours or man-years is not an adequate measure of labor. Then, too, U.S. agriculture is a sizable aggregate, and as one has recourse to index numbers, all of the limitations of such indexes put in their appearance.

To make the problem at hand manageable requires that one arrive at a judgment on the nature and importance of these difficulties and on the relevancy of each of the possible explanations already referred to. To do this adequately would require, I fear, a book. I can only touch on them at this time.

Output Estimates[15]

It is my belief that flaws in these estimates are not of major importance to the problem presented here, but, even so, they cannot be dismissed out of hand. These output estimates for U.S. agriculture, in the main, are based on products that are fairly standardized and for which there are market prices. The prices of most of these products have not changed a great deal relative to each other over the years, and, thus, the particular set of prices that are used as weights in an index of output do not present a serious problem. One should be mindful, however, that the quality of some farm products has improved and that these improvements are not taken into account.

The output attributed to farm dwellings (included in some output measures) is on less firm ground; it is an imputed value, and it is weak because there are few market prices at hand to check against. More important, in my judgment, are the following ommissions: (1) "improvements in the

[15] For a very useful discussion of concepts, methods of estimating, and statistical reliability, see *Major Statistical Series of the U.S. Department of Agriculture*, Agricultural Handbook No. 118, especially Vol. 3, December, 1957.

farm plant resulting from the farmer's own labor and from other labor and materials on the farm" are ommitted; the formulation of such self-made farm capital must have been large in earlier decades and it may still be all too substantial to leave out;[16] (2) nor is there any allowance for depletion of natural resources on farms and here, too, the score has been changing over the years; and (3) no account whatsoever is taken of the gains in leisure (time) that has been occurring on farms.[17]

Despite these omissions, one may decide to take the output estimates as they are. But, even then, it will make considerable difference which of the available measures of agricultural output oue chooses. For example, between 1940 and 1953, agricultural output represented by four USDA and Kendrick's measures show the following increases: (1) *volume of farm marketings and home consumption* rose 35 per cent; (2) *Kendrick's gross output* for the farm sector, 31 per cent; (3) *farm output*, 30 per cent; (4) *real gross farm income*, including inventory changes but excluding government payments, 26 per cent; and (5) *gross farm production*, only 22 per cent.

Input Estimates

These estimates are not on nearly as good a footing as are those of output. The difficulties are several and they run deep, both conceptually and in measurement, and one would think that these difficulties should be dealt with before proceeding to the underlying physical and economic relationships between output and inputs.

It is my belief that one of the major reasons why the estimates of output and input diverge arises out of defects in concepts and measures of inputs. This is one of the main reasons why I find Heady's approach to these output-input relationships not adequate to the task. Although at the outset of his paper, page 394, he refers twice to Land Grant college education as

[16] Tostlebe, Alvin S., *Capital in Agriculture: Its Formation and Financing Since 1870*, Princeton University Press, 1957, an NBER study. His estimates of farm real estate have much to commend them. But, in my judgment, they underestimate appreciably the increases in farm structures that are included in farm real estate. Many of these structures have been self-made farm capital, especially during the earlier decades of the period covered by Tostlebe. The USDA has not estimated this component; hence, there are no data and Tostlebe chose not to enter without data to fortify his position.

[17] In rcent decades, agricultural production has produced not only more products, but it also had mode possible more leisure on farms. This is a component that belongs in agricultural output. See, Simon Kuznets on this point and his estimates of the value of leisure appearing in Table 7 of *Income and Wealth of the United States*, Bowes and Bowes, Cambridge, England, 1952.

Self-made capital, depletion of natural resources, and leisure are relevant not only for agricultural output of a country but also in determining the output of particular farms; and yet, as a rule, they are not taken into account, although it should be much easier to do so at that level than it is in national agricultural output estimates.

having improved the quality of farmers, not even this one change in quality, and it is only one of many that may be observed, appears explicitly in his representations.[18]

The task of getting at the defects in our concepts and measures of agricultural inputs goes far beyond the scope of this paper. Moreover, Griliches has a study underway in which he is concentrating on this and some closely related problems. It would be premature and, also, inappropriate to me to anticipate the results of his study.

There are, however, several general characteristics of these input estimates on which a comment may be in order: (1) Most of these inputs are not standardized components as are most of the products that make up agricultural output: (2) The value put on many important agricultural inputs,or on the service of a resource that renders it, is an imputed value. For some of these, there are at hand no satisfactory explicit market prices to use as checks; for example, the labor of the farmer and of members of his family and the productive services obtained from some of the durable capital forms, although these capital goods are being bought and sold. (3) Some inputs are omitted, for instance, the labor and materials used in the formation of self-made capital on farms. (4) A serious defect is the failure to account adequately for improvements in the quality of both physical and human inputs. (5) The relative prices of these inputs have been changing greatly, especially since about 1940, and these changes in relative prices place severe limits on what can be done in constructing useful indexes of such inputs.

Other Considerations

In considering the role of returns to scale, I have only two comments. Studies of particular farms that have developed estimates of the underlying production function would appear to underestimate "returns to scale" because of specification bias.[19] Glenn L. Johnson has advanced some cogent reasons for believing that substantial specialization has been occurring in U.S. agriculture as a whole it has produced appreciable "returns to scale."[20] Both of these should be pursued as leads for research. I, for one,

[18] At one point, in (14) on page 400, Heady introduces a subscript to reflect ". . . the new forms of resources. . . ." This could be construed in such a way as to make room for changes in quality of inputs. However, in the context of the paper, it would seem to apply to components, such as, ". . . ammonium nitrate, 2,4-D, Pioneer 907 hybrid seed corn, row crop tractors and irrigation water in Indiana . . .," referred to on page 396, and not, for example, to improvements on the quality of farmers resulting from the work of the Agricultural Extension Service.

[19] See Zvi Griliches, "Specification Bias in Estimates of Production Functions" *Journal of Farm Economics,* Vol. 39, February, 1957. Griliches sees this as the plausible consequence; he, however, points out that the resulting bias could in fact run either way.

[20] See Johnson's paper cited in footnote 3.

however, beg to remain skeptical on the point that such returns to scale are of themselves of major importance to the problem at hand.

From the late thirties to the late forties and to the present, it seems to me that there has been a substantial reduction in the price risks and uncertainty confronting many farmers and that this development, along with the stronger capital position of farmers, has reduced capital rationing measureably in agriculture.[21] If true, it should have affected output-input relationships and it should, therefore, be taken into account.

More important, however, than changes in returns to scale, or reduction in risk and uncertainty, or a turn in "weather", is the underspecifications of human and physical capital components that contribute to the improvements in the quality of human effort and of physical capital. These components are important; they have been increasing proportionately more than have conventional inputs. In my judgment, a substantial part of the otherwise unexplained growth in agricultural output is attributive to these underspecified components.[22]

All these and technical improvements too are relevant and, I would think, necessary in explaining the growth in agricultural output. The particular set of output-input relationships that Heady discussed in his paper is only a small part of the story.

[21] Also, see Glenn L. Johnson on this point, *ibid.*

[22] A measure of one of these components for the economy as a whole would be education. I have completed a set of estimates of the gross capital formation represented by the four high school years and for education beyond the twelfth year of school in the U.S. These estimates show that in 1920 it was, in billions of dollars at current prices, equal to 7 per cent of the gross capital formation of the conventional sort (using Kuznets estimates) and in 1956, it was equal to 28 per cent of gross conventional capital formation. See my, "The Emerging Economic Scene and Its Relation to High School Education," *The High School in A New Era*, edited by Francis S. Chase and Harold A. Anderson, University of Chicago Press, 1958. Table I, page 106.

EFFECTS OF FERTILIZER USE ON BARLEY IN NORTHERN MANITOBA*

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THERE is an increasing demand for further data on fertilizer experiments in Canada. Farmers, extension personnel, soil scientists, agronomists and economists all have an interest in fertilizer use.

The present paper reports on the results of a fertilizer investigation at

* The field work for this paper was carried out at the Wabowden Substation, Manitoba, under the general supervision of R. M. Hopper, Superintendent, Brandon Experimental Farm, Canada Department of Agriculture.

** Formerly of the Dominion Experimental Farm Service, Canada Department of Agriculture, now with the Kurth Malting Company, Milwaukee, Wisconsin.

the Wabowden experimental substation in northern Manitoba. While the results are from only one year's data (1956), the analysis contained in this paper presents some interesting implications for crop production on the "climatic frontier" of agriculture in Manitoba.

Description of the Area

The Wabowden experimental substation is situated on the fifty-fifth parallel, approximately one-third of the way between The Pas and Churchill on Hudson's Bay. The substation is located in a clay belt of potentially arable land estimated at four million acres. The soil at Wabowden is a grey wooded, solonetzic soil.

The length of the growing period at Wabowden is one of the critical, limiting factors for agricultural development. Unofficial records suggest the average frost free period to be from 90 to 95 days. However, one of the compensating factors for the relatively short growing period is the greater number of hours of sunlight during the summer months. The Wabowden substation receives approximately 60 hours more sunlight during June, July and August than does the area around Brandon in southern Manitoba. The average temperature for the period May 1 through September 30 was 53 degrees for the years 1946 to 1951.

Description of the Experimental Design

The design of the fertilizer experiment was a six by six triple lattice repeated.[1] This type of design gave six replicates and each replicate contained six blocks of six plots each. The test consisted of nitrogen and phosphate being applied at the following rates per acre: 0, 20, 40, 60, 80 and 120 pounds. Nitrogen (N), in the form of ammonium nitrate (35.5-0-0), and phosphate (P_2O_5), in the form of triple superphosphate, were applied to a crop of Parkland barley.

Only 20 pounds of the N fertilizer were sown with the seed. This anticipated the possible detrimental effect of high levels of the N fertilizer on the seedlings. The remainder of the N fertilizer was broadcast over the plot rows at the time of plant emergence. The triple superphosphate was applied at the time of seeding the crop.

The six by six triple lattice repeated design permitted six replicates of each fertilizer level and a total of 216 observations. This design allowed the conventional analysis of variance treatment of the observations as well as providing estimates of the production responses in terms of a multiple regression equation. The regression model used was that of the following general form:

$$Y = f(a + b_1N + b_2P + b_3N^2 + b_4P^2 + b_5NP)$$

[1] Cochran, W. G. and Cox, G. M., *Experimental Designs*, New York: John Wiley and Sons, New York, 1950, pp. 309 ff.

This type of equation allowed total diminishing product as well as an interaction term between N and P_2O_5.

The regression equation was used to estimate: (1) the relationship between barley yield and varing levels of N and P_2O_5; (2) the relationship between days to maturity and levels of N and P_2O_5.

Empirical Results

The statistical methodology used in the analysis of the fertilizer data has already been described elsewhere.[2] Three different regression functions were used to express the relationship between barley yield and varying levels of N and P_2O_5.

(A) *Quadratic equation*

$$Y = 8.2714 + 0.2715N + 0.3106P - 0.00201N^2 - 0.00140P^2 + 0.0006NP$$

(B) *Square root equation*

$$Y = 8.31 - 0.1319N - 0.0350P + 1.6590\sqrt{N} + 1.8404\sqrt{P} + 0.1020\sqrt{NP}$$

(C) *Logarithmic equation*

$$Y = 7.5509N^{0.0971}P^{0.2444}$$

A quadratic equation was also used to express the relationship between days to maturity and varying levels of N and P_2O_5. This equation took the following form:

(D) $$Z = 102.3 - 0.0136N - 0.2478P + 0.0005N^2 + 0.0010P^2 + 0.0006NP$$

In this equation Z, the dependent variable, expresses the number of days between seeding and harvesting (days to maturity).

TABLE 1. COEFFICIENT OF DETERMINATION AND THE T-TEST FOR THE REGRESSION COEFFICIENTS OF THE FOUR EQUATIONS

Equation	Value R^2	Value of t-test for the regression coefficients of the following terms				
		N	P	N^2 or N	P^2 or $\sqrt{P}$	NP or $\sqrt{NP}$
A	.8422**	4.62**	5.28**	4.64**	3.23**	1.45+
B	.8667**	2.80**	.74	2.74**	3.03**	2.13*
C	.8819**	1.83*	4.59**	—	—	—
D	.8146**	.32	6.10**	1.60*	3.40**	0.70

\+ Significant at the 10 per cent level.
* Significant at the 5 per cent level.
** Significant at the 1 per cent level.

[2] For example see: Baum, E. L., Heady, E. O. and Blackmore, J. (editors), Ames: Iowa State College Press, *Methodological Procedures in the Economic Analysis of Fertilizer Use Data*, 1956.

Data in Table 1 give the t-tests for the coefficient of determination and regression coefficients for the four prediction equations. The R^2 values tested significant at the 1 per cent level for all four equations.

Equation A (quadratic function) was used as the basis for discussion in the remainder of this paper. While there was little to choose between equations A and B, the t-tests for the regression coefficients in equation A appeared to yield slightly better results than those of equation B. The t-tests for equation A also conformed with the results from the analysis-of-variance treatment of the data. The F-test for the effects of N, P and the interaction effect all tested significant in the analysis-of-variance treatment of the data.

The actual barley yields and the yields estimated from equation A are shown in Table 2. It will be observed that the estimated yields conformed very closely to the actual barley yields. Both diminishing marginal returns and total diminishing product can be observed from the data in Table 2. For example, with P_2O_5 held constant at 20 pounds per acre and N increased from 0 to 120 pounds per acre, barley yield increased at a diminishing rate from 13.92 bushels to a maximum yield of 23.74 bushels. The yield dropped back to 19.0 bushels with N at 120 pounds per acre.

It will be noted that a diminishing total product accompanied the higher levels of N fertilizer input. At the higher levels of N, excessive leaf growth and lodging were apparent. There was no evidence in the present data of a diminishing total product for the higher levels of P_2O_5. Soil scientists observed that a maximum physical yield of barley would have been attained for an input of P_2O_5 at some point beyond 120 pounds per

TABLE 2. ACTUAL AND PREDICTED YIELDS OF BARLEY AT VARYING LEVELS OF N AND P FERTILIZER NUTRIENTS

	Lbs. N					
Lbs. P_2O_5	0	20	40	60	80	120
0	8.27*	12.80	15.91	17.32	17.13	11.91
	7.8**	9.6	13.2	16.0	12.2	9.0
20	13.92	18.79	22.04	23.69	23.74	19.00
	20.2	22.1	27.2	26.2	23.4	23.1
40	18.45	23.56	27.05	28.94	29.23	24.97
	18.8	26.0	29.0	38.0	26.4	29.3
60	21.87	27.22	30.95	33.08	33.61	29.83
	15.3	22.1	26.9	28.9	28.7	32.1
80	24.16	29.75	33.72	36.09	36.86	33.56
	23.2	27.9	33.0	37.9	37.0	31.7
120	25.38	31.45	35.90	38.75	40.00	37.66
	27.5	31.9	37.0	40.2	44.0	33.6

* Upper figure in each cell was the predicted barley yield from the quadratic equation.
** Lower figure in each cell represents the barley yield from the actual experiment.

acre. It was also pointed out that a diminishing total yield would not have occurred as the P_2O_5 input was extended beyond the maximum physical yield. Excess P_2O_5 tends to become fixed to the calcium in the soil. Soils around Wabowden tend to be phosphate deficient. The explains the relatively greater yield response to P_2O_5 as compared to the N fertilizer.

The effect of the positive interaction term (0.0006NP) may be noted in the yield increases along the northwest-southeast diagonal line of Table 2.

Substitution Between N and P_2O_5 in Producing Specified Yields

The data given in Table 3 show the various combinations of N and P_2O_5 fertilizer elements in producing specified yields of barley. These combinations of N and P_2O_5 were derived from equation A. For example, zero pounds of N and 50 pounds of P_2O_5 will produce 20 bushels of barley. The 20 bushels may also be produced by substituting some N for P_2O_5, or using a combination of 10 pounds of N and 34 pounds of P_2O_5. At the other extreme, 40 pounds of N and 16 pounds of P_2O_5 will also

TABLE 3. COMBINATIONS OF N AND P_2O_5 TO PRODUCE TWO GIVEN YIELDS OF BARLEY AND MARGINAL REPLACEMENT RATES OF N AND P_2O_5[1,2]

20 Bus. Barley			30 Bus. Barley		
Lbs. N	Lbs. P_2O_5	Rate of substitution of P_2O_5 for N (Lbs. P_2O_5 replaced by 1 lb. N) $\frac{dP}{dN}$	Lbs. N	Lbs. P_2O_5	Rate of substitution of P_2O_5 for N (Lbs. P_2O_5 replaced by 1 lb. N) $\frac{dP}{dN}$
(1)	(2)	(3)	(4)	(5)	(6)
0	50	−1.77	20	83.0	−2.67
10	34	−1.14	25	71.9	−1.73
20	24	− .81	30	64.0	−1.27
30	17	− .58	40	54.0	− .78
40	16	− .42	50	48.0	− .49
			55	46.0	− .37
			60	44.0	− .26
			70	42.5	− .07

[1] The iso-quant was derived from the following equation:

$$P = -(.3106 + .0006N) \pm \frac{\sqrt{.0965 + .00058N + .00000036N^2 - .00560\ (8.27143 + .2715N - .00201N^2 - Y)}}{-0.0028}$$

[2] The marginal rate of substitution of P_2O_5 for N was derived from the following equation:

$$\frac{dP}{dN} = -\frac{0.2715 - 0.0040N + 0.0006\ P}{0.3106 - 0.0028P + 0.0006\ N}$$

produce 20 bushels of barley. Similarly, the various combinations of N and P_2O_5 in producing 30 bushels of barley are given in Table 3.

The marginal rate of substitution of N for P_2O_5 at various combinations of the two fertilizer elements is given in columns 3 and 6 of Table 3. It will be noted that a diminishing marginal rate of substitution existed between the two fertilizer elements. Column (3), for example, shows the rate at which N substitutes for P_2O_5. At the point where zero pounds of N and 50 pounds of P_2O_5 are used to produce 20 bushels of barley, one additional pound of N will replace 1.77 pounds of P_2O_5. At the other extreme (40 pounds of N and 16 pounds of P_2O_5) one pound of N will replace only 0.42 pounds of P_2O_5.

The data in Table 3 are illstrated in Figure 1. The 20, 30 and 35 bushel yield contours are given. The isocline JB illustrates all points where the marginal rate of substitution of N for P_2O_5 (dP/dN) is 0.57. For example, at the points a, b and c, one pound of N will substitute for 0.57 pounds of P_2O_5. The marginal rate of substitution (dP/dN) at all points on the isocline KC is 1.75.

The least-cost combination of N and P_2O_5 in producing a given yield is determined by equating the marginal rate of substitution of N for P_2O_5 (dP/dN) to the inverse price ratio, P_N/P_P. For example, with the price of N at 8 cents per pound and the price of P_2O_5 at 14 cents per pound, the

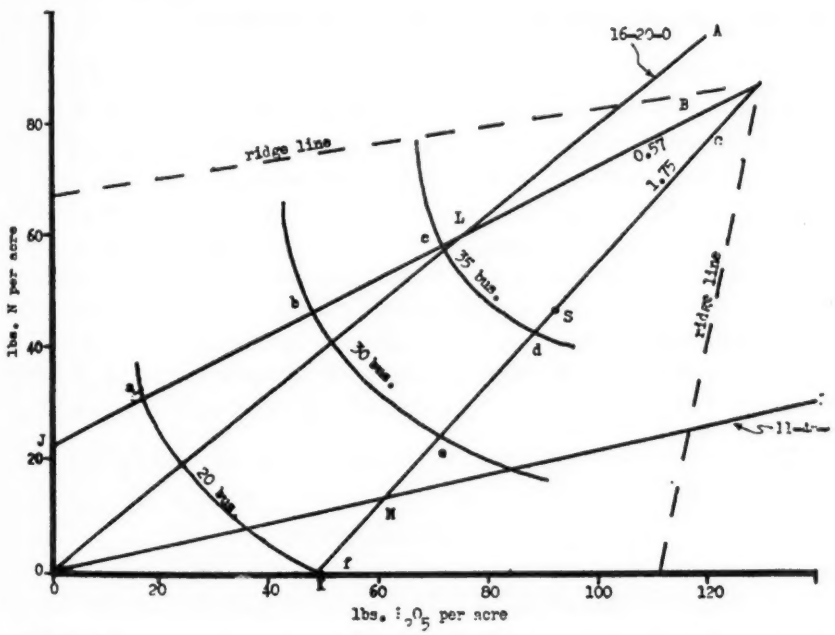

FIG. 1. COMBINATIONS OF N AND P_2O_5 IN PRODUCING SPECIFIED YIELDS OF BARLEY

price ratio P_N/P_P, is 0.57. Thus the least cost combination of N and P_2O_5 coincides with all points on the isocline JB. Similarly, with the price of N at 14 cents and the price of P_2O_5 at 8 cents, the least-cost combination of these two elements lies along the isocline KC (the price ratio P_N/P_P in this case is 1.75).

The ratio between N and P_2O_5 for the two most common fertilizers in Western Canada (11-48-0 and 16-20-0) is shown on lines OD and OA respectively. With the two assumed price ratios given above, these two types of fertilizers happen to yield the least cost combination of N and P_2O_5 at only two points, L and M (Figure 1).

The general significance of finding the least-cost combination of fertilizer nutrients may be illustrated by comparing the costs of two different combinations of N and P_2O_5 in producing 30 bushels of barley. In one case, 19.2 pounds of N and 84 pounds of P_2O_5 (in the form of 11-48-0 fertilizer) could be used. This point is found where line OD intersects the 30 bushel yield contour in Figure 1. The total cost of the fertilizer in this instance, with the price of N at 8 cents per pound and the price of P_2O_5 at 14 cents, would be $13.30. On the other hand, the least-cost combination of N and P_2O_5, with the given prices, would occur at point b on the isocline JB. The total cost of the fertilizer at this point would be $10.24. Thus difference in cost per acre between the two fertilizer combinations is $3.06. Similar cost calculations could be made for any other combinations of N and P_2O_5 in producing a given yield of barley.

Determination of the Most Profitable Application of N and P_2O_5

Consideration has been given to the least-cost combination of N and P_2O_5 with specified prices for the two fertilizer elements. The next step in the analysis must also consider the most profitable level at which N and P_2O_5 could be applied, given the price of barley. Assuming the following prices: P_N at 14 cents per pound, P_P at 8 cents per pound and barley at $1.00 per bushel, the most profitable application of the two fertilizer elements occurs at 92.2 pounds of P_2O_5 and 46.7 pounds of N.[3] The corresponding yield was 35.9 bushels of barley. The most profitable application of the two fertilizer elements, at the assumed prices, is shown in Figure 1 at point S. The most profitable application of N and P_2O_5 for

[3] The most profitable application can be found by a simultaneous solution of the following equations:

$$\text{(E)} \qquad \frac{\partial Y}{\partial N} = 0.2715 - 0.0040N + 0.0006P = \frac{P_N}{P_Y}$$

$$\text{(F)} \qquad \frac{\partial Y}{\partial P} = 0.3106 - 0.0028P + 0.0006N = \frac{P_P}{P_Y}$$

other prices of N, P_2O_5 and barley, can be similarly determined by simultaneous solution of equations (E) and (F).

Two aspects of the above analysis should be noted. It would not be practical for farmers to attempt to apply the exact amounts of N and P_2O_5 as indicated by the optimum. Yields are never that certain and in addition, it may not be practical or convenient to apply N and P_2O_5 in the exact ratio indicated by the optimum. However, the foregoing analysis does indicate the need for modification of the conventional recommendations on fertilizer use. First of all, the level of fertilizer used should depend on the price relationships between the fertilizer elements and barley. In the second place, the least-cost combination of the fertilizer elements depends on the price ratio and the marginal rate of substitution between N and P_2O_5. Experimental data of the type included in this paper provide the criteria by which practical recommendations on fertilizer use may be made.

Relationship Between Fertilizer Application and Days to Maturity

The experiment at Wabowden was also designed to test the effect of fertilizer on the length of time required for the barley to reach maturity. The amount of time for grain to reach maturity in this northern area, where the frost-free period is a critical, limiting factor, is extremely important.

Regression analysis of the data at Wabowden yielded the following equation:

$$Z = 102.3 - 0.0136N - 0.2478P + 0.0005N^2 + 0.0010P^2 + 0.0006NP$$

The estimated days to maturity at varying levels of N and P_2O_5 are shown in Table 4.

TABLE 4. RELATIONSHIP BETWEEN VARYING LEVELS OF N AND P_2O_5 AND PREDICTED DAYS TO MATURITY OF BARLEY*

Lbs. of P_2O_5 per acre	Lbs. of N per acre					
	0	20	40	60	80	120
0	102.3	102.2	102.5	103.3	104.4	107.9
20	97.7	97.6	98.0	98.7	99.8	103.3
40	94.0	93.9	94.3	95.0	96.1	99.6
60	91.0	90.9	91.3	92.0	93.1	96.6
80	88.9	88.8	89.2	89.9	91.0	94.5
120	87.0	86.9	87.3	88.0	89.1	92.6

* The data for this table were derived from the following equation:

$$Z=102.3-0.0136N-0.2478P+0.0005N^2+0.0010P^2+0.0006NP$$

It will be noted that successively higher levels of nitrogen had the effect of lengthening the days to maturity. While the coefficient of N in the above equation is negative (tendency to reduce days to maturity), the positive effect of the N^2 coefficient more than offset the effect of the N coefficient, the net result being one of increasing the days to maturity at successive higher levels of the nitrogen fertilizer.

By contrast, the days to maturity were reduced at higher levels of P_2O_5. For example, with zero pounds of N and P_2O_5 raised from zero to 120 pounds per acre, the days to maturity were reduced by 15.3 days. On the other hand, with P_2O_5 at zero and N raised from zero to 120 pounds per acre, the days to maturity were lengthened by 5.6 days.

It is obvious that P_2O_5 fertilizers could assume a very important place in the development of areas where the growing period is severely limited. It is a well established fact in experimental work in Manitoba that P_2O_5 tends to reduce the days to maturity. At the present time, soil scientists are not prepared to offer any physiological explanation for this inverse relationship between P_2O_5 and days to maturity. On the other hand, N tends to increase days to maturity because of the fact that higher levels of N tend to promote correspondingly more leaf and stem growth on the plant.

Many more investigations will need to be carried out in this region before general inferences may be drawn with respect to the relationship between fertilizer level and the corresponding yields and number of days for grain to reach maturity. Further studies might indicate that P_2O_5 fertilizers could be as valuable for their effect on reducing the days-to-maturity as that of increasing yields. It will also be necessary to carry out further investigations to determine the optimum rate of nitrogen use from the standpoint of both yield increases and days-to-maturity.

Conclusions

The primary objective of this paper was to examine the methodological procedures needed in the analysis of fertilizer data. The triple lattice repeated design not only permitted the traditional analysis-of-variance treatment of the data but also yielded data that were very adaptable to regression-analysis procedures.

Three different regression equations were fitted to the data. The quadratic function was selected for the analysis. The quadratic function was also used to analyze the relationship between fertilizer use and the corresponding amount of time for the barley to reach maturity.

The regression-equation approach to the analysis of fertilizer yield data is an extremely useful device. The regression equation not only expresses the physical relationship between fertilizer level and yield,

but also permits one to determine the least-cost combination of fertilizer elements, as well as to determine the most profitable application of fertilizer.

The inferences from the present experiment are limited to one year's data. Further investigations will be needed. However, the one year's data does point up some general tendencies which have rather interesting implications for the land area around the substation at Wabowden.

A GRAPHIC METHOD FOR PRESENTING A MARGINAL ANALYSIS USING FEED SUBSTITUTION AND PRODUCTION FUNCTIONS

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THIS paper presents a mash-grain substitution function and a feed-turkey production function that can be used in estimating optimum economic conditions for feeding and marketing turkeys. Included is a graphic method for presenting a marginal analysis in which price ratios are used as indicators for optimum feed substitution and production conditions.

During the 1956 production season, turkey producers in North Dakota submitted semi-monthly reports on their costs, returns and practices in producing 46 flocks of turkeys. Marketing weights and feed consumption information from these reports, together with turkey growth functions derived from secondary data, were used in developing the feed substitution and production functions presented in this paper.[1] Three logarithmic, or Cobb-Douglas, substitution functions were derived for the grain feeding period for turkeys from 60 to 180 days of age, and two quadratic production functions were derived for finishing hens and toms.[2] The Cobb-Douglas function for the 100-139 day grain feeding period and the quadratic function for finishing toms have been selected to illustrate the graphic method used in presenting the marginal analysis.

The graphs were constructed in the following manner: 1. Production data relevant to the marginal analysis were fitted by regression to the selected types of curvilinear functions. 2. Solutions to the fitted functions

[1] The secondary data are that of the Poultry Division, Dominion Experimental Farms, Ottawa, Ontario, as taken from Marsden and Martin, *Turkey Management*. The Interstate, Danville, Illinois, sixth edition, 1955, pp. 321-23.

[2] A more comprehensive description of the turkey study and the statistical methods used are contained in the following unpublished M. S. thesis: Hovey, Roy M., *Input-Output Relationships in Turkey Production*, Agricultural Economics Department, North Dakota Agricultural College, Fargo, North Dakota, January, 1958.

and their first derivatives were tabulated for a selected series of values falling within the range of the production data. The solutions for the differential equation were designated as inverse price ratios. 3. Using appropriate scales, the points determined by the tabulated values for the integral and differential functions were plotted on the graphs and the curves were drawn. Thus, the production data are represented in three parallel ways, in the equations, tables, and graphs.

The marginal analysis feature of the graphs results from plotting the differential functions and designating the scale for the curves as inverse price ratio values. The integral curves are plotted for reference to corresponding values for the integral functions.

In order to represent the substitution relationship between mash and grain for the three 40-day gain feeding periods, Cobb-Douglas functions of the form

$$T = aG^bM^c$$

were fitted by multiple regression to logarithms of the data for turkey growth and feed consumption. In these equations T is the estimated number of pounds gained per turkey during the period, G is the number of pounds of grain consumed per turkey during the period, and M is the number of pounds of mash consumed per turkey during the period. To assure that the results would be representative of straight-run turkeys, the growth was estimated and feed consumption data were taken from the records for 23 of the 46 flocks having more than 47.5 and less than 52.5 per cent toms.

The grain-mash substitution functions for the three periods were computed from the Cobb-Douglas production functions, using the average gain per turkey for the 23 flocks during each period as the constant value of T. Finally the derivative (G′) of the grain-mash substitution function is the equation for computing all mash-grain price ratios which are equal to the inverse of the marginal rate of substitution between grain and mash.[3]

Selecting Optimum Mash-grain Feeding Rates

The fitted Cobb-Douglas production function for the second growing period (100 to 139 days of age) was

$$T = 4.39G^{.0648}M^{.0816} \quad (1)$$

The average production per turkey during this period was 6.14 pounds of gain in body weight. The mash and grain fed contained 32 and 12 per cent protein, respectively.

[3] In this paper mash designates any kind of commercially premixed feed regardless of its form. Grain designates all kinds of feed grain and includes grain screenings.

When the value of T in equation (1) was assumed to be 6.14 pounds, the consequent grain-mash substitution function was found to be

$$G = 177M^{-1.26} \quad (2)$$

The derivative of equation (2) is:[4]

$$G' = 222M^{-2.26} \quad (3)$$

Solutions to equations (2) and (3) for selected mash feeding rates are given in Table 1 and Figure 1.

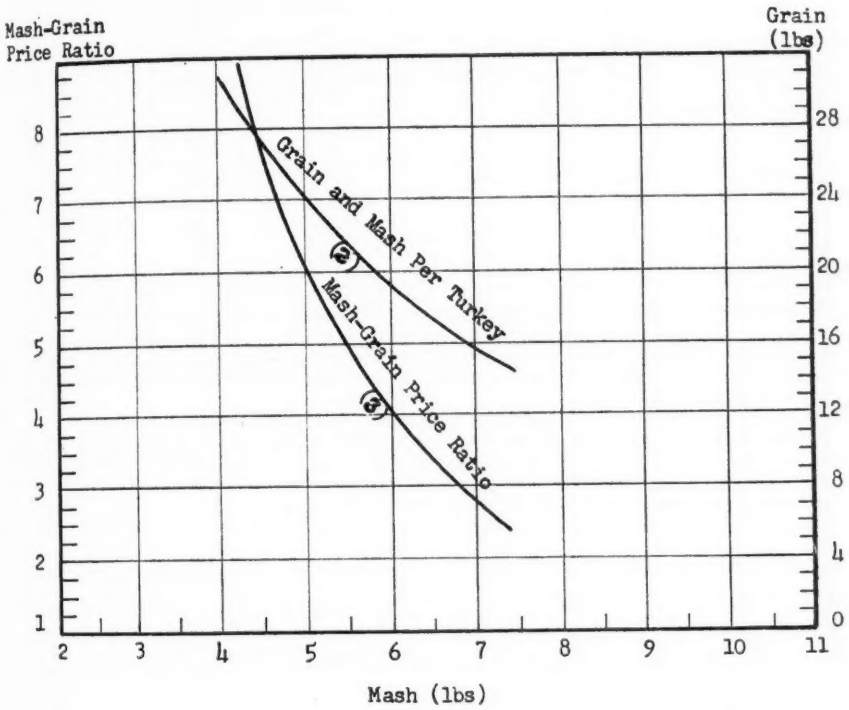

FIG. 1. GRAIN-MASH SUBSTITUTION FUNCTION AND MASH-GRAIN PRICE RATIO FOR TURKEYS 100-139 DAYS OF AGE.

Explanation

The selected mash feeding rates are given in Table 1, column one.[5] Solutions for the substitution functions are given in column two and solu-

[4] This mathematical procedure follows that used in reporting a measurement of the corn-soybean oil meal isoquants at the Iowa Experiment Station. See Heady, Balloun and Dean, *Least-Cost Rations and Optimum Marketing weights for Turkeys,* Research Bulletin No. 443, Agricultural Experiment Station, Iowa State College, Ames, Iowa, October, 1956.

[5] As explained in footnote a of Table 1, the upper limit for total grain and mash consumption is based on the turkeys' physical capacity for feed consumption.

TABLE 1. OPTIMUM FEEDING RATES PER TURKEY AND COST OF RATION PER 1000 TURKEYS FOR TURKEYS 100 TO 139 DAYS OLD

(1) Optimum Feeding Rates[a]	(2) Optimum Feeding Rates[a]	(3)	(4) Cost of Ration per 1000 Turkeys[d]	(5) Cost of Ration per 1000 Turkeys[d]	(6) Cost of Ration per 1000 Turkeys[d]
Mash (32 Per Cent Protein)	Grain[b] (12 Per Cent Protein)	Mash-Grain Price Ratio[c]	Mash ($5.24 per CWT.)	Grain ($1.60 per CWT.)	Total
lbs.	lbs.		dol.	dol.	dol.
4.2	29.0	8.7	220	464	684
4.7	25.2	6.7	246	403	649
5.2	22.2	5.4	272	355	627
5.7	19.7	4.4	299	315	614
6.2	17.8	3.6	325	285	610
6.4	16.9	3.3	335	270	605
6.7	16.1	3.0	351	258	609
7.2	14.7	2.6	377	235	612
7.7	13.5	2.2	403	216	619
8.2	12.5	1.9	430	200	630
8.7	11.6	1.7	456	186	642

[a] Optimum feeding rates are limited by (1) feasible mash-grain price ratios, (2) the physical capacity of the bird to consume feed, (3) nutritional levels consistent with good growth. The maximum physical capacity for feed consumption was established by adding approximately 10 per cent to the 30.4 pounds consumed by the 46 flocks. The recommended protein level is from 14 to 17 per cent.

[b] Grain feeding rates were computed for the selected mash rates using equation (2).

[c] Computed from equation (3) for the selected mash feeding rates. A price ratio smaller than 1.7 is outside the range of the data for the 46 flocks. The applicable mash-grain price ratio for the 46 flocks was 3.3.

[d] Average feed prices are for the 46 flocks, 116 to 131 days old.

tions for the derivative are listed in column three. The optimum mash and grain feeding rates can be read from the table for the price ratios listed. A cost of ration illustration is presented in the right half of the table to show the manner in which costs are minimized when the price ratio, $5.24/$1.60, or 3.3, is used as an indicator.

The graphic solutions for the substitution functions[6] and their derivatives may be used to estimate the optimum amounts of mash and grain for a given mash-grain price ratio as follows:

1. Select the applicable mash-grain price ratio on the left scale.
2. Move horizontally to the right to the point of intersection with the mash-grain price ratio curve.
3. Move vertically upward or downward to the point of intersection with the grain and mash per turkey curve. The optimum amount of mash

[6] The curve for the grain-mash substitution function is the isoquant for the average production per turkey during the period. This curve represents various quantities of mash and grain inputs required to produce a constant quantity of turkey output during the period.

may be read from the mash scale vertically below this point, and the corresponding optimum amount of grain may be read from the grain scale horizontally to the right of this point.

Feed-turkey Production Functions and Maximum Profits

Profitability of the turkey enterprise is governed by the continuously changing technical efficiency with which turkeys convert costly productive resources into a valuable product. Where a marginal analysis of productivity is employed to estimate optimum conditions for maximum feeding profits, the entrepreneur weighs the marginal cost of the resources against the marginal value of the resulting product. Equations representing decreasing technical efficiency were used for the analysis for the finishing period.[7]

The type of equation selected was the quadratic production function of the general form,

$$T = a + bF + cF^2$$

where T is the total pounds weight per turkey and F is the total pounds of feed consumed per turkey. Separate equations for hens and for toms were fitted to growth, mortality, and feed consumption data.[8]

For toms, the fitted production function is

$$T = 6.57 + .212F - .000514F^2 \quad (4)$$

and the derivative is

$$T' = .212 - .00103F \quad (5)$$

Solutions to equation (4) are listed in column 3 of Table 2 for feed consumption at 10 day intervals.

[7] Each type of equation lends a characteristic mathematical bias to the marginal analysis. Flock management considerations were used in preference to statistical measures of goodness of fit in selecting the type of equation used. A linear equation is unsuitable for a marginal analysis. Its constant derivative would indicate either-or choices such as all mash or all grain rations, and feeding to produce finishing gains or immediate sale of turkeys. The Cobb-Douglas function was selected for the substitution analysis because its derivative indicates choices of optimum mixtures of mash and grain as the proportion of grain is increased during the course of the grain feeding period. All of the 46 producers started their poults on an all mash ration and some of them fed all grain in the final weeks of the finishing period. The use of the quadratic equation for the finishing period brings the production analysis to a climax. The mathematical characteristics of the quadratic curve reflect diminishing returns in the North Dakota turkey flock at the onset of the winter season, when maturing birds are decreasing in efficiency of feed conversion and the feeder is threatened with losses in total flock weight through death of heavy birds and adverse weather conditions.

[8] Mortality losses for the 10 day periods were estimated using the equation, $M = 1.46 - 1.6D + .62D^2$, where M is the number of death losses during the 10 day period, and D is the age in days at the midpoint of the period. This function was fitted to mortality data for the 46 flocks for the period from 31 to 200 days of age.

The derivative is designated as the feed-turkey price ratio and solutions are listed in column 4 of the table. The corresponding graphic solution is represented in Figure 2, and is read in the same manner as the one for the feed substitution function and its derivative.

TABLE 2. FEED-TOM PRICE RATIOS AND OPTIMUM MARKETING CONDITIONS FOR MAXIMUM FEEDING PROFITS FOR TOM TURKEYS 140 TO 220 DAYS OF AGE FOR 46 FLOCKS

(1)	(2)	(3)	(4)
Age of Tom	Optimum Conditions per Tom		Feed-Tom Price Ratio[c]
	Total Feed Consumption[a]	Total Body Weight[b]	
days	lbs.	lbs.	
140	63.0	17.9	.147
150	72.1	19.2	.138
160	81.8	20.4	.128
170	92.3	21.7	.117
175	98.4	22.4	.111
180	103.5	23.0	.105
190	115.0	24.1	.093
200	127.3	25.2	.081
210	140.4	26.2	.067
220	153.8	27.0	.054

[a] Derived from data for the 46 flocks for ages listed in column 1.
[b] Computed from feed consumption amounts in column 2 using equation (4).
[c] Computed from feed consumption amounts in column 2 using equation (5).

For illustrative purposes, it was estimated that the average marginal feeding cost per hundredweight of feed was $2.59 for the 46 flocks. The average live turkey price per hundred weight was $23.42 for all toms sold. Using this information, the feed-turkey price ratio for the average flock was .111 for toms. Using the .111 as an indicator and referring to Table 2 and Figure 2, it is found that the conditions for maximum feeding profits are at approximately 22.4 pounds weight per tom, 98.4 pounds feed consumed, and 175 days of age.

Use of Information

Although the material presented is based on actual data, it was developed for conceptual purposes rather than for practical use. However, the information in Table 1 and Figure 1 may be used to determine the amounts of mash and grain to feed at various mash-grain price ratios. The accuracy of any such recommendations is dependent upon the similarity of conditions in the flock for which the recommendations are being made and the average conditions from which the basic functions were

derived. The tendency toward the average conditions, or the mean for the values fitted, results from the fact that all values pass through the mean and that use of neither an all mash nor an all grain ration is permitted by the conceptual characteristics of the mathematical model used.

Likewise, the material in Table 2 and Figure 2 may be used to estimate the optimum marketing conditions for varying feed-turkey price ratios. These estimates would also be characterized by limitations similar to those previously stated for estimating the optimum amounts of mash and grain to be fed at various mash-grain price ratios.

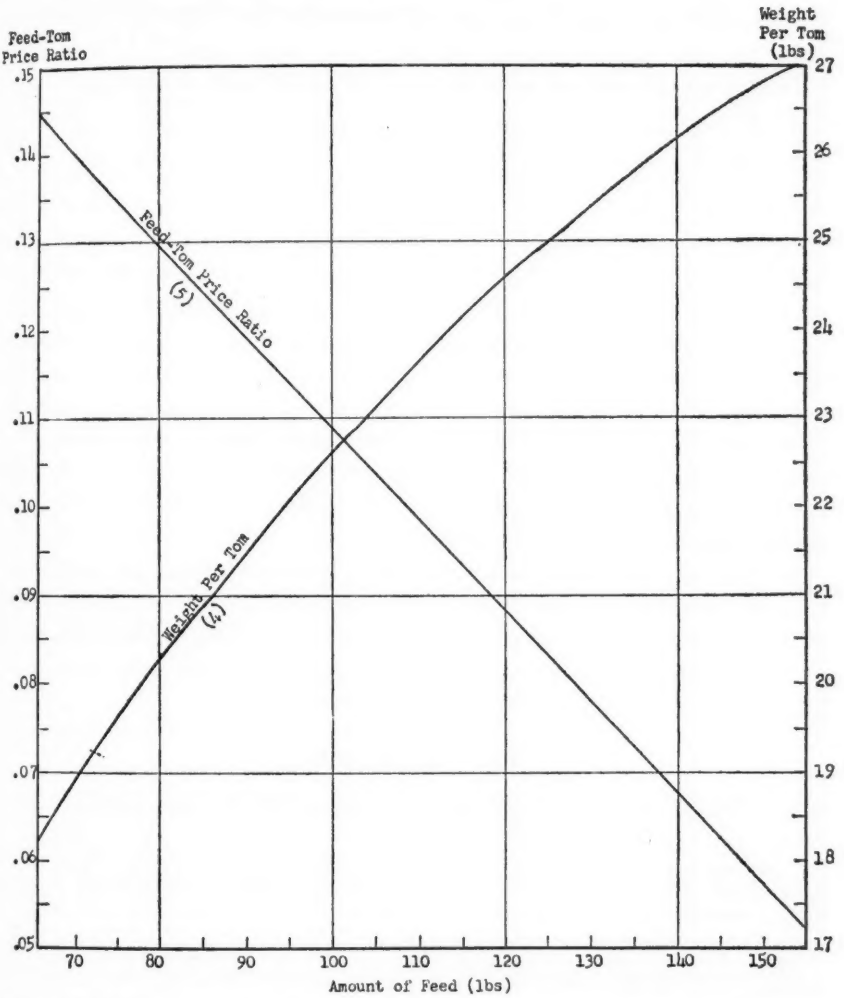

FIG. 2. WEIGHT-FEED PRODUCTION FUNCTION AND OPTIMUM FEEDING RATES FOR VARYING FEED-TOM PRICE RATIOS FOR TURKEY TOMS 140-220 DAYS OF AGE.

GRADING OF CARNATIONS, CHRYSANTHEMUMS AND SNAPDRAGONS IN RELATION TO ECONOMIC MARKETING CONDITIONS IN SPOKANE, WASHINGTON*

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State College of Washington

MANY members of the florist industry in the Pacific Northwest want standard grading, but few have attempted to grade. At present, the only grades promoted to any extent are the Society of American Florists (SAF) standard grades, which determine quality primarily by weight. The SAF standards have not been used much because growers are uncertain that such a grading system would be accepted by retail florists.

In this experiment, answers to these questions were sought:

1. Will grading by SAF standards be profitable for the grower?
2. Will the market differentiate prices for the various grades?
3. How will retail florists react to graded cut flowers?

In 1948, Post[1] suggested a system of cut-flower grades based upon weight. He stated that there was a high correlation between cut-flower quality and weight per stem. Post believed that weight accounted for size and length of stem and size of flower, but weight could not take into account color, crooked stems, and old or misshappen flowers. Such defects would have to be eliminated by a sorter. The grades proposed by Post were known as CSW (Cornell Standard Weight) grades and were adopted by the New York State Flower Growers Association in 1948. However, resistance to grading developed, and in 1951 Brookins[2] noted that few growers continued to grade.

In 1953 the SAF adopted the CSW grades for carnations and snapdragons as SAF standard grades. In 1954 CWS grades for standard chrysanthemums, pompon chrysanthemums, stocks and iris were endorsed as SAF standard grades. The SAF has been attempting to secure the acceptance of grading by the florist industry.

The Spokane Market

In 1954, 46 growers in Spokane County, Washington, reported sales

* Scientific Paper No. 1646 Washington Agricultural Experiment Station, Pullman. Work conducted under Project No. 1308 contributing to Western Regional Project WM24.

** Present address: University of Maryland.

[1] Post, K., "Weight Grading of Cut Flowers," *New York State Flower Growers Bulletin*, 1948, 30:4-7.

[2] Brookins, H. B., "Merchandising Starts with the Grower," *New York State Flower Growers Bulletin*, 1951, 75:2-4.

of cut flowers, potted plants, florists greens and bedding plants amounting to $663,325. Two wholesale florist firms, one of them a cooperative, serve Spokane and the surrounding area of Eastern Washington, Northern Idaho, and Western Montana.

Methods and Materials

Three greenhouse operators and the two wholesale florist companies in the Spokane area helped conduct the marketing experiments. SAF standard grades were used for carnations, pompon chrysanthemums and snapdragons. The graded bunches were marked by appropriately colored tags stamped with names of the grades and the grower's number as suggested by SAF.

Grading on this experiment started during the first week of March, 1956, and was continued until the last week of February, 1957. All three growers graded their carnations, and one of them graded pompon crysanthemums and snapdragons. The two wholesale florist firms in the area cooperated by keeping records of sales, prices and dumpage of graded and ungraded stock. The dumpage was considered important because locally grown stock is sold by wholesale florists on consignment. A dumping rate was calculated by the formula:

$$\frac{\text{Number of Flowers Dumped}}{\text{Total Flowers on Hand}} \times 100$$

Data were obtained on carnations for 12 months, on pompon chrysanthemums for seven months, and on snapdragons for nine weeks.

An attempt was made to estimate and compare the quality of ungraded and graded carnations by examining ungraded carnation samples on the market during the last seven months of the experiment.

Reactions to the use of grades were obtained by interviewing eight Spokane retail florists in 1956.

Results and Discussion

A. *Grades and Price Differentiations*

Carnations

Average monthly prices for the different carnation grades are in Table 1. Special grade carnations were not produced during the final three months of the experiment because of cloudy weather in the Spokane area.

After an initial period of three months, during which wholesalers hesitated to differentiate between grades by price, the market differentiated between all of the carnation grades except between Special and Fancy.[3]

[3] Price differences between Fancy and Extra, between Extra and First, and between First and Utility, each tested significant at the 1 per cent level.

TABLE 1. AVERAGE MONTHLY PRICES RECEIVED FOR GRADED AND UNGRADED CARNATIONS, AND MONTHLY INDICES OF QUALITY OF GRADED CARNATIONS

Month	Special	Fancy	Extra	First	Utility	Ungraded	Index of Quality
			Cents per Flower				(%)
March	11.33	11.86	12.01	10.85	8.40	10.57	98
April	10.91	10.95	11.44	9.67	7.41	9.71	102
May	10.55	11.88	10.98	9.17	8.50	10.02	104
June	9.17	9.03	8.94	7.33	7.33	7.97	106
July	7.00	8.88	8.36	7.46	6.43	7.42	103
August	11.00	10.62	9.17	6.88	5.77	7.69	100
September	12.00	10.71	8.60	6.25	6.65	7.83	99
October	12.00	10.72	8.72	6.81	6.46	7.96	99
November	10.00	11.54	9.30	7.31	6.03	8.51	100
9 Month Ave.	10.45	10.67	9.67	7.66	7.40	8.78	101
December	—	14.04	12.15	10.38	7.83	10.84	99
January	—	12.45	11.22	8.13	6.82	9.67	95
February	—	12.63	11.74	9.46	8.10	10.64	93
12 Month Ave.	—	11.07	10.16	8.01	7.48	8.72	100

Retailers were not prepared to pay a premium for any carnation higher in quality than Fancy; presumably their customers were not sufficiently interested in quality to pay the difference. As a result, some weeks the Specials, after being in the wholesaler's refrigerator for a few days, were sold at a price lower than Fancies to move them before they become unsalable.

A complicating factor in making comparisons was the arrival on the market of higher quality carnations from California, which brought higher

TABLE 2. ADJUSTED MONTHLY PRICES FOR GRADED AND UNGRADED CARNATIONS (INCLUDING AND EXCLUDING CALIFORNIA STOCK) AND MARKET GAIN OR LOSS OF GRADED OVER UNGRADED CARNATIONS

Month	Graded	Ungraded		Market Gain or Loss	
		Including California	Excluding California	Including California	Excluding California
		Cents per Flower			
March	10.53	10.54	10.41	−0.01	+0.12
April	9.98	9.80	9.50	+0.18	+0.48
May	10.53	10.08	9.81	+0.45	+0.72
June	8.04	7.60	7.21	+0.44	+0.83
July	7.66	6.53	6.16	+1.13	+1.50
August	8.29	7.35	6.21	+0.94	+2.08
September	7.48	8.06	6.85	−0.58	+0.63
October	7.81	7.99	7.48	−0.18	+0.33
November	8.08	8.18	7.91	−0.10	+0.17
December	10.99	11.59	10.47	−0.60	+0.52
January	8.96	9.74	9.42	−0.78	−0.46
February	9.72	11.05	10.42	−1.33	−0.70

prices than most local stock. To compare carnations grown under similar local environmental conditions, the effect of California carnations had to be removed from the data for ungraded carnations. During the late summer and fall, when total sales of carnations were relatively low, California stock constituted from one-fourth to one-third of the total. (Figure 1)

Adjusted prices were calculated by multiplying the average monthly price by the percentage of the flowers not dumped. Table 2 shows ad-

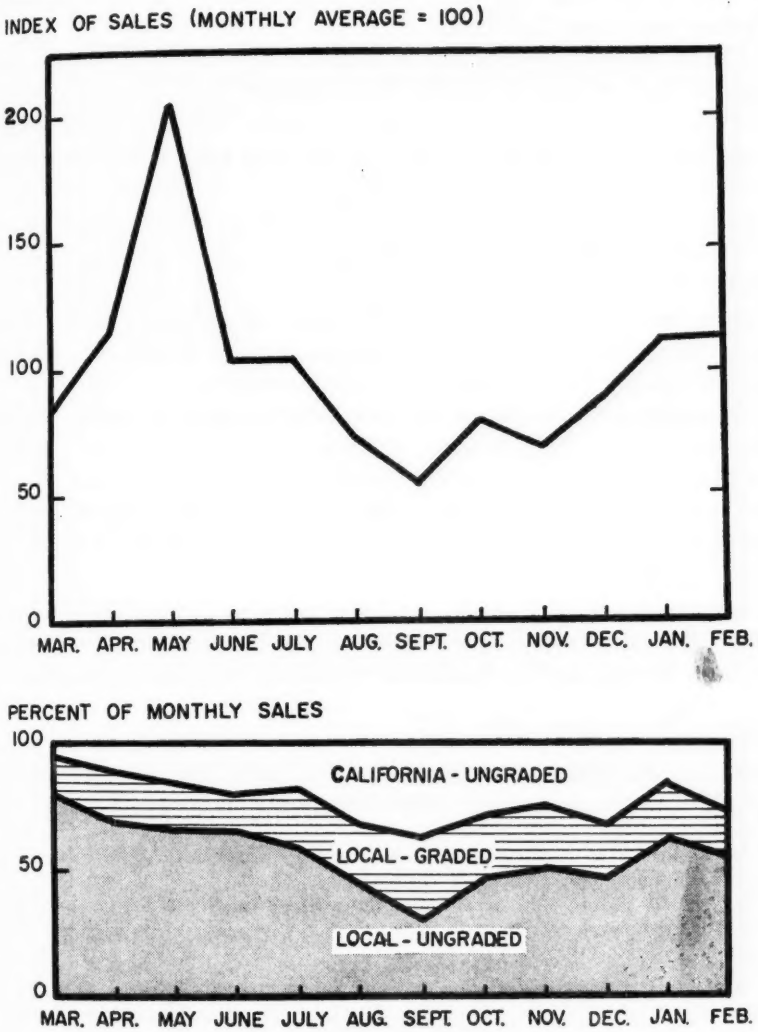

FIG. 1. INDEX OF SALES OF CARNATIONS BY MONTHS AND PROPORTION OF SALES THAT WERE GRADED, UNGRADED, LOCAL AND CALIFORNIA STOCK

justed prices for graded and ungraded carnations and market gain or loss, both including and excluding California carnations.

Over the 12-month period there was no significant difference between the prices of the graded carnations and the ungraded carnations with the California stock included. If California stock were excluded, the graded carnations had an advantage of 0.33 cents per flower over ungraded carnations.

The sampling of ungraded carnations indicated that there was little difference in the range of quality between graded and ungraded carnations including those from California.

An index of quality was prepared in an attempt to explain the variations in market gain or loss of graded over ungraded carnations. This quality index was calculated for each month and for the full year by determining the percentage that each grade was of the total graded flowers received. These percentages were then multiplied by the average prices for the respective grades as of November 30, the last month in which Specials were produced. The products of the percentages $\times$ prices were added together; then each monthly total was divided by the yearly total.[4] Thus, the index varies from month to month because of changes in the proportions of the grades, not because of changes in price. The resultant monthly indices of quality were presented in Table 1.

The quality indices were correlated with the market gain or loss both with and without the influence of California stock. Lines of regression were fitted by the least squares method (Figure 2 and Figure 3). In each case the market gain increased as quality increased. It seems that grading is worthwhile for the grower who can produce average or better than average quality.[5]

Grading costs, including labor and the cost of scales and materials were estimated at 0.24 cents per flower, with the cooperation of one grower who kept records for two weeks on the labor required for grading.

Pompon Chrysanthemums

Pompon chrysanthemums were graded from April 6 to October 26, 1956. The pompon grading cooperator discontinued grading in late

[4] This method was suggested by E. J. Working, Chairman, Department of Agricultural Economics, State College of Washington.

[5] The annual market gain or loss and the average quality index of the three cooperating growers were as follows:

Grower	*Average Quality Index*	*Market Gain or loss (cents per flower)*
A	98	−0.21
B	102	+0.62
C	101	+0.79

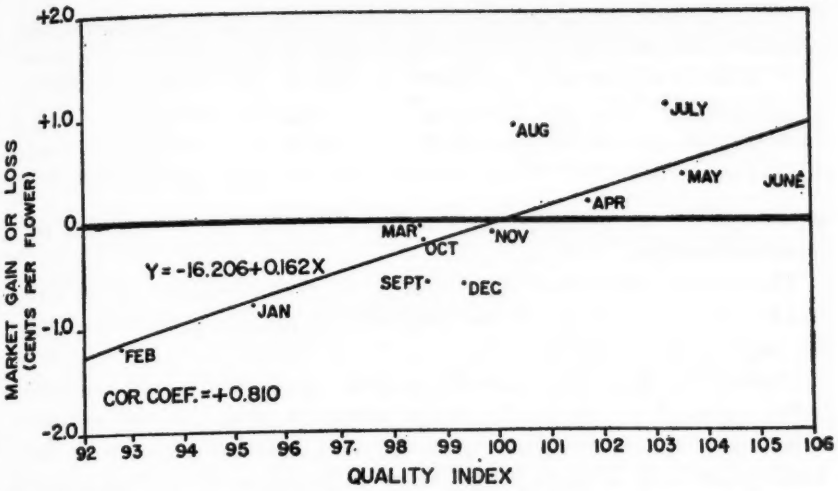

FIG. 2. REGRESSION OF MARKET GAIN OR LOSS (DATA ON CALIFORNIA STOCK INCLUDED) ON QUALITY MARKETED

October because he felt that his graded stock was being sold at a disadvantage to bunches of ungraded pompons which contained more stems than allowed by the SAF grades. Average pompon prices are presented in Table 3. Utility grade pompons could not be compared with

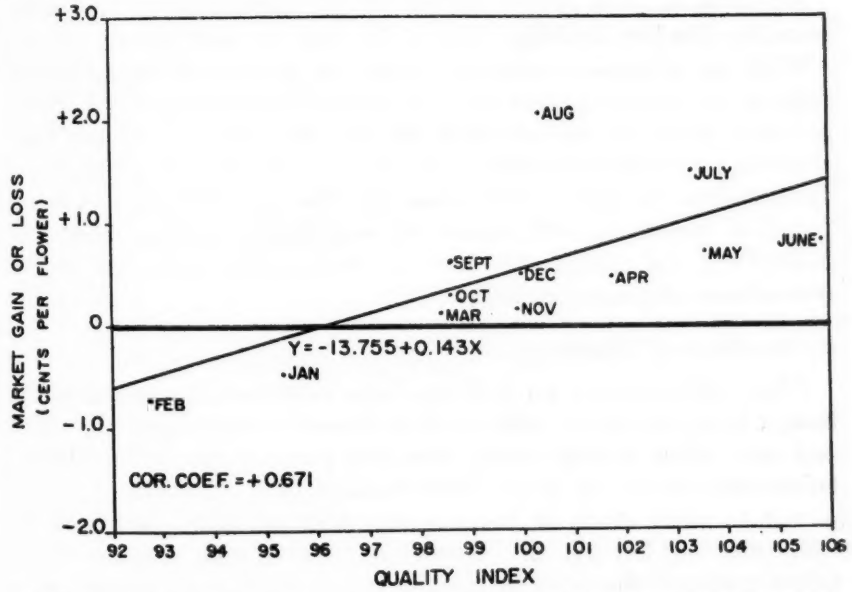

FIG. 3. REGRESSION OF MARKET GAIN OR LOSS (DATA ON CALIFORNIA STOCK EXCLUDED) ON QUALITY MARKETED

TABLE 3. SEVEN-MONTH AVERAGE PRICES FOR GRADED POMPOM CHRYSANTHEMUMS

Price	Special	Fancy	Extra	First	Utility
Dollars per bunch	1.18	1.32	1.10	0.91	0.78
Cents per stem	29.53	22.04	18.29	15.19	—

other grades on a cents-per-stem basis because they were put up in 8-ounce bunches.

The market established significant price premiums between the various grades. During each month the price of a grade was greater than that of the adjacent lower grade.

During the final three months graded pompons were in competition with ungraded pompons. Ungraded pompons were put up in 10-ounce bunches, so that comparison had to be on a cents-per-ounce basis. When both prices and dumping rates were included in the calculations, the premium received for graded pompons was 0.57 cents per ounce over ungraded pompons.

Although costs of grading and comparisons of quality were not calculated, apparently pompon grading would pay if the grower could produce better than average stock.

Snapdragons

Snapdragons were graded by one of the cooperators for nine weeks, from May 4 to July 29, 1956.

While no comparison of quality between graded and ungraded snapdragons was obtained, there was a sizeable difference in price: 2.23 cents per stem. As in the case of carnations, Specials sold for a slightly lower price than Fancies, presumably because retailers were not willing to pay the premium. However, there were sizeable price differences between the other grades. As with carnations, snapdragon grading seems to be profitable if the growers can produce high-quality stock. The grading system is no substitute for quality.

B. Reactions of Retailers

When eight Spokane retail florists were interviewed, only one said he bought by grade, using Utility stock for funeral work, hospital containers, and sales where a long, strong stem was not important. The other retailers did not buy by grade either because they visited the market in person to select stock, or because they had standing orders with the wholesaler and left selection of stock to his discretion. Some of the retailers criticized the pompon grading system saying pompon quality is not important except during the holiday seasons, because it is used mostly as a "filler" flower.

Out-of-town retailers have found that the greatest advantage of grading is being able to order the quality desired for specific uses even though they are distant from the market. A major weakness of the grading system in this experiment was the lack of a system for compelling strict adherence to the grades. There is obviously a need for an impartial agency to police the grading and enforce penalties upon those who consistently abuse the grades. The four-stem bunch of Special grade pompons is unpopular. Special grade pompons might well have the same number of stems as other grades.

Conclusions

1. The market developed significant price differences between all SAF carnation grades except between Special and Fancy. It seems possible that these two grades could be combined for the Spokane market.
2. In carnations there was little difference in price or quality between graded and ungraded stock. The market gain of graded over ungraded local stock is 0.33 cents per flower. If the cost of grading (0.24 cents per flower) is deducted, then the graded stock has a price advantage of 0.09 cents per flower or 2.25 cents per bunch.
3. The market gain of graded carnations over ungraded carnations tends to increase as the quality of graded carnations improves. Thus, grading is worthwhile for the producer of quality stock. Grading is no substitute for quality.
4. The limited data on sales of graded pompon chrysanthemums indicated a good price differential between SAF grades and also that there was a slight market gain for graded over ungraded stock.
5. Many retailers were more interested in large bunches than in quality in pompons. Because of competing bunches with many stems, the stems-per-bunch requirement should be waived on the SAF standard grades until more control can be exerted over producers to bunch to a set standard.
6. Retailers objected to the 4-stem special grade pompon bunch. Pompon grading would be more acceptable to Spokane retailers if the Special pompon grade contained the same number of stems as the other grades.
7. The limited data on snapdragons indicated that significant price differences developed between SAF grades and between graded and ungraded stock. For the Spokane market it seems desirable to combine the Special and Fancy grades.
8. Out-of-town retailers like being able to order by grade when occasion requires. However, they complain that growers do not always adhere strictly to the grading standards. Stricter supervision of grading seems necessary.

INTERNATIONAL WHEAT SURPLUS UTILIZATION CONFERENCE

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South Dakota State College

AN INTERNATIONAL Wheat Surplus Utilization Conference was held at South Dakota State College July 20 to August 9. Its purposes were limited to three objectives:

(1) To determine the size and extent of present wheat surpluses and the prospects for the next few years.

(2) To evaluate existing methods of surplus disposal, especially Public Law 480.

(3) To examine the possibilities of expanding the use of surplus wheat.

The conference was sponsored by South Dakota State College and partially financed by contributions from 18 farm organizations.

A total of 145 people participated. Forty-one participants were from 20 foreign countries. These included representatives of governments, agricultural organizations, attachés and students. The American representatives included 39 members of farm organizations in the Great Plains, 27 economists from universities and colleges, 25 individuals from the private grain companies or private life, and 13 government people. Playing a key role in the conference was Mordecai Ezekiel of the Food and Agriculture Organization (FAO) headquarters in Rome.

Thirty-five papers were presented. They included papers by Ezekiel, Helen Farnsworth, Don Paarlberg, Theodore Schultz and Wilfred Melenbaum. Copies of all these papers are available from the Economics Department, South Dakota State College. The proceedings of the conference will be available early in 1959.

Afternoon sessions were devoted to discussions of the papers and attempts to arrive at conclusions concerning the three problems posed above. The consensus of the group on these three problems seemed to be:

Size and Extent of the Wheat Surplus

1. The world is producing about as much wheat as it can consume, under present conditions, including concessional sales at recent levels.

2. There has been a sharp upward trend in unsold carry-over stocks in major exporting countries during the last six years, flattening off in 1957/58 and 1958/59.

3. As long as the present system of arrangements for government protection to agricultural incomes, trade barriers, etc., in importing and exporting countries continues as it has in recent years, and as long as technology of production continues to result in rising yields as it has been

doing, there seems unlikely to be any material change in this general surplus situation, despite the continuing increase in population.

4. Independent measures of surplus disposal may, therefore, assume a semi-permanent character, and affect an increasing part of the international trade in grains, thus adding to the marketing difficulties now being experienced by exporting countries.

Evaluation of Public Law 480

It is in the interest of farmers and the general public that existing surplus food supplies be used as fully as possible to speed up economic development in the less developed countries of the world. Public Law 480 has attempted to do this. This has the desirable effects of increasing present levels of nutrition in underdeveloped countries, raising their ability to produce, speeding up the rate of progress in production; levels of national income, and consumption; and making their countries better able to buy and sell in foreign trade with other countries. Countries that are in a position to help, notably the United States, should therefore continue and expand their aid to the economic development of less developed countries by all feasible means, including direct assistance in international financing as well as provision of surplus foods. To facilitate these activities, the following legislative or administrative changes seem needed in Public Law 480:

1. *Public Law 480 should be amended so as to authorize agreements under Title I for periods of as much as five years ahead with only the costs during each year of such agreement to be charged to that year's appropriation.* This change would enable recipient countries to develop firm plans for development projects, to use the funds for a suitable period ahead, to arrange for domestic sale of surplus products, and to simultaneously use the foreign currency resulting from those sales for expanded development projects. Owing to inevitable delays in reaching agreement and in conducting operations, most countries find it difficult or impossible to get the projects started within the present one year period. Most development projects take several years to carry to completion, and many governments hesitate to make surplus food distribution arrangements or to put new development projects into operation when they have no assurance that resources will be available to carry those operations through to completion.

2. *The sections of Public Law 480 dealing with the assurance that recipient countries will continue commercial imports at their previous levels should be strengthened to afford as much protection to exports by other friendly nations as they give to exports by the U.S.* This might be done by stating the required guarantees under Public Law 480 in the same way as they are stated under the Mutual Security Act. The present language in Public Law 480 and the present agreements may result in substituting

U.S. commercial exports for those by other exporters, which is contrary to the spirit of the FAO Principles of Surplus Disposal, to which most countries, including the U.S., have subscribed. To further assure the maintenance of commercial exports, consultation with other exporting countries should be further developed.

3. *The use of local currency proceeds for expenditures that would otherwise be paid in dollars should be limited to the minimum amount possible.* These expenditures frequently run to 50 per cent or more of the total value of the surpluses received. In part these are used to pay the recipient country for services or commodities which would otherwise be paid for in dollars. To that extent they reduce the effectiveness of the operations in increasing domestic consumption of the products distributed or in providing increased expenditures for economic development. Since they do not increase the recipient country's capital formation, and tend to harm other exporting countries by substituting U.S. exports (paid in dollars) for purchases from other exporters, they represent an addition to the program contrary to its stated purposes and objectives, and should, if possible, be eliminated entirely.

4. *Countries should be given the maximum flexibility possible to select their own development projects to be financed from amounts earmarked for local currency loans, wherever the effectiveness of their own administrative arrangements justify.* The elaborate administrative procedures of prior approval by the U.S. greatly slow up the earmarking and expenditure of funds for development, and tend to result in expenditures for additional employment lagging far behind the actual sale of the commodities in domestic markets. More general adoption of the principle of allocation by the country concerned with subsequent report to the U.S. authorities, which has been permitted in some cases, would be helpful.

5. *Barter deals should be restricted to the minimum possible and the recent administrative requirement for proof that additional consumption would result should continue to be strictly enforced.* Surpluses disposed of earlier under barter or triangular deals have tended to be substituted for other commercial imports, rather than to be offset by increased food consumption in the recipient country. This is especially true when a highly developed country is a party to the transaction. Substituting U.S. wheat for wheat exports by other countries does not raise world wheat consumption nor reduce world wheat carry-overs; operations which have this effect harm other friendly nations.

6. *Food-surplus-producing nations should have as the primary objective of their surplus disposal programs the increasing of the recipient country's real national income in such a manner that it will result in the broadest possible distribution of benefits.*

The United States as a nation has successfully pursued the objective of rapid economic growth through a free private enterprise economy. However, it should be recognized that imposing from the outside some types of economic arrangements on certain nations may not be compatible with achieving this objective of rapid economic growth. Some nations lack the United States' tradition of checks and balances, such as our anti-trust legislation, in their economic system. Without these checks and balances, free private enterprise frequently fails to channel new income to the needy consumer or to productive enterprise. The promotion of our particular ideas of competitive enterprise, while a desirable objective under appropriate conditions in some countries, should be a secondary consideration to a substantial volume of surplus disposal and an equitable distribution of the benefits from the disposal programs.

Possibilities of Expanding the Use of Surplus Wheat

1. *The use of wheat surpluses for educational purposes should be expanded as rapidly as possible.* This expansion might include:

(a) The use of food scholarships for local and foreign high school and college students in the recipient country.

(b) The use of local currency for the expansion of personnel, facilities, and financing for the training of teachers.

(c) The use of local currency for the expansion of personnel, facilities, and financing for research in economic development in the recipient countries.

These efforts should raise the level of literacy and of professional, technical and administrative training, all of which are necessary for economic development.

2. *Authorization might well be made for the provision of surplus foods (a) to provide initial stocks of food grains for recipient countries to establish or enlarge national food reserves for use in emergencies; (b) to help finance the construction of storage facilities for holding such reserves; and (c) for the replenishment of such reserves, once they were drawn upon.* The initial stocks might be provided either under Title I or Title II, and replenishment might be made under either of these titles, or by commercial imports, depending upon the circumstances of use. An international committee, such as an appropriate FAO committee or group of experts, might pass upon the purpose for which used and the conditions for replenishment.

3. *The use of food surpluses for school lunch programs should be expanded as rapidly as possible and as fast as recipient countries can develop proper measures for operating them and using the surplus foods for this purpose.* This would not only improve nutrition and the health of the

students, but should encourage larger and longer school attendance and reduction of illiteracy. In countries that are just starting or expanding such programs, arrangements might be made by the country concerned to use CARE or a similar agency as an operating agency, possibly using local currencies available under Title I.

4. *Some countries have used surplus foods in kind to enable settlers on newly opened land to get through the first year.* This method of disposal might be further expanded, and perhaps applied in appropriate community development projects for increasing productive capacity.

5. *The use of surplus feeding stuffs to improve livestock production in recipient countries should be further developed.* In many cases small amounts of supplementary feeding during periods of poor pastures or at certain times of the year (i.e. sheep in North Africa, dairy cattle or beef cattle in Central or South America) can greatly increase livestock production. Use of surplus foods for such supplementary feeding can materially increase livestock products available to offset increased development expenditures and at the same time may demonstrate the economic value of subsequent commercial import of feedstuffs for such supplementary feeding. The feedstuffs should be distributed to farmers as mixed or processed feeds or in some other manner to avoid diversion to other use.

6. *The use of surplus food for refugees and displaced persons should be expanded wherever possible* with special emphasis on creating employment and making them self-sufficient members of society.

7. There are many other possibilities of expanding the effective use of surplus foods for improved nutrition and increased economic development, and vigorous and imaginative research should be continued for such uses, both in private and public discussions and actions. The same applies to many other ways and means not considered at the conference: such as more positive organization for this purpose perhaps in the form of a world food bank or world food reserve, or by encouraging research in food preparation to make wheat as acceptable and easily prepared as possible.

Other Limiting Factors for Greatly Expanded Use of Wheat

1. *Additional dollar support to additional development projects will often be needed to supplement the surplus foods,* if increased food consumption is to equal the amount of surplus products sold into domestic markets in the recipient country. This might be obtained either by providing additional cash loans or grants for economic development projects in the same Act to be used for combined "package deals" along with surplus products, or by directing that such arrangements might be worked out in conjunction with other legislation (such as Mutual Security activities) as part of the general U. S. policy to stimulate and speed up the economic development of less developed nations.

It might also be possible to provide that repayment of loans under the Marshall Plan, or local currency repayments under Title I of Public Law 480 should be paid into a revolving fund to be added to other funds available to expand Public Law 480 Title I operations.

2. *The "Market basket" of surplus products covered by disposal agreements should be as wide and varied as possible,* and cover as much as possible of the increased domestic purchases of persons put to work on additional developmental projects, for maximum effectiveness in financing additional economic development and for not reducing markets for commerical exports. In addition to wheat, rice, dry milk, and other dairy products, vegetable oils, cotton, beans, poultry and livestock products might be included where available in surplus stocks. In addition, feed grains might be included on condition they would be used to expand livestock production (poultry and dairy products, and meats) to be used to offset the increased consumption. (Such feeding stuffs should be distributed to farmers in the form of processed or mixed feeds to prevent their diversion from the use intended).

3. *More information is needed about the economic development process both in donor countries and in recipient nations and about the effect of surplus disposal on economic development.* Much more can be done in the way of research and education on such problems as evaluating the effects of Public Law 480 transactions on the economies of recipient countries on normal commercial markets, and on the relation of better nutrition to human energy and productivity.

While there are many difficulties involved in Public Law 480 operations they are far outweighed by the highly desirable consequences of using surpluses constructively in underdeveloped nations and every effort should be made to continue to improve and expand on the surplus disposition programs that have been instituted. Public Law 480 should not, however, be expanded at the expense of other programs for dollar grants or loans for economic development in other countries.

MODIFICATION OF LINEAR PROGRAMMING SOLUTION ROUTINE TO PERMIT CONSIDERATION OF CONDITIONAL RESTRICTIONS*

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FREQUENTLY in linear programming problems, the level of entry of a particular process is subject to direct restriction.[1] In some cases the restrictions will be relevant; in all other cases, they could be ignored. This situation has been handled by including these restrictions in the problem. This increases the problem size both with respect to each iteration and the number of iterations required to reach solution. It has also been handled by developing models that assume either that the restriction is effective or that it is not.[2] In case the initial assumption is incorrect a solution may be obtained by solving the alternative model or by adjustment in the solution obtained upon the "wrong" model. Where the number of such restrictions is few, this is a feasible alternative, but, when the number is larger and permutations are possible, this procedure becomes difficult to apply. An alternative to these procedures is presented below.

In case a conditionally restricted process is in solution in excess of its maximum limit the following adjustment routine is indicated. Subtract the maximum limit from the level of entry leaving the remainder in the solution vector. Increase the cost or reduce the revenue of the process by an arbitrary amount sufficient to force the process to leave the solution on subsequent iterations. When the process is forced out of the solution, the new solution will be subject to the restrictions that would apply, had the restrictions in the initial problem been modified to reflect the entry of the restricted process at its maximum. It is also necessary to sense the decoded zj − cj value for the process blocked in the solution at its maximum in all subsequent iterations. It may happen, for example, that upon subsequent iterations the blocked process would fall below the maximum if permitted to do so. This would be indicated by the turning

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[1] That is, the particular process and that process alone is subject to one or more of the restrictions of the problem.

[2] As an example of a model, in which the restrictions that are specific to single processes are included, see Hutton and Allison, "A Linear Programming Model for Development of Feed Formulas Under Mill-Operating Conditions" *Journal of Farm Economics*, Vol. 39, February 1957, p. 94.

As an example of a model in which the restrictions that are specific to single process are not included see Hutton and McAlexander, "A Simplified Feed-Mix Model" *Journal of Farm Economics*, Vol. 39, August 1957, p. 714.

of the decoded zj − cj to a positive value. If this occurs, correction may be made by (a) reducing the costs or increasing the revenue of the adjusted process to make its zj − cj "most negative," (b) iterating one tableau, (c) adding the maximum limit to the level of entry in the solution vector, and (d) restoring the original decoded cj value to the process. Subsequent iterations will lower the level of entry below the maximum for this process.

In case the level of entry of a process falls below a permitted minimum, it is necessary to first bring the level up to the minimum by giving the process an artificially favorable cj value. The minimum is then deducted from the entry in the solution vector and the cj is restored to its original value. Upon subsequent iterations the process will leave the solution vector and the solution will reflect the optimum subject to the restricted process being entered at its indicated minimum. This process may re-enter the solution upon still later iterations. In this event, the solution level of the restricted process is the level indicated in the solution vector plus the minimum level.

Of course, if a process must always be included at the same minimum level, it is simpler to adjust the initial problem statement to reflect this condition. The procedure outlined above is suitable for problems in which the minimum level may change from one situation to another. A mix problem in which all of the available supply of an ingredient must be used and the available supply is variable represents a concrete case where this procedure is applicable.

The use of this procedure saves computer time only if changes in effectiveness of the restrictions are relatively infrequent. Again this is often the case in feed formulation problems. Ingredients that are restricted in their level of entry may be so high in price, relatively, that the upper limit is ineffective for months on end. Then, they may become relatively favorable in price and remain so for several months. Seasonal fluctuations in prices may cause such behavior.

The program of a digital computer used in solving linear programming problems can be modified to automatically perform the operations indicated above. Constants for the limits on each restricted process would need to be read in with prices or revenues at each run of the problem.

THOMAS POE COOPER, 1881-1958

THOMAS POE COOPER died in Lexington, Kentucky, February 19, 1958, in his 77th year. Although most of his life was spent as an administrator, he was an agricultural economist at heart. He served as president of the American Farm Economics Association in 1923 and was Chief of the Bureau of Agricultural Economics, U. S. Department of Agriculture in 1925-26. He maintained his membership in the association throughout his active life. In recognition of his professional attainments he was awarded honorary degrees by Clemson Agricultural College, the University of Minnesota and Georgetown College.

Born in Pekin, Illinois, March 2, 1881, he received the B. S. in Agriculture from the University of Minnesota in 1908. He was an assistant in farm management there until 1911 when he became Director of the Better Farming Association of North Dakota. From 1914 to 1917 he was Director of the North Dakota Experiment Station and Extension Service. On January 1, 1918, he became Dean of the College of Agriculture and Home Economics, Director of the Agricultural Experiment Station, and Director of Agricultural Extension at the University of Kentucky, the position he held until July 1, 1951, when he was placed on emeritus status. During the year 1940-41 he served also as acting president of the University.

Dean Cooper was an exceptional administrator and a tireless worker with the ability to carry a load of responsibilities such as few men have been able to carry. He was a keen judge of human nature. His capacity to grasp problems quickly, to formulate plans for their solution, and to direct the thinking and efforts of others made him a natural leader. His counsel frequently was sought by government officials, by bankers, by business associates and by the minister of his church to which he gave devoted service. He was deeply interested in students and frequently helped them by an encouraging word or in some material way.

He was president of the Association of Land Grant Colleges and Universities in 1946, after having served as secretary of the association for a period of 16 years. Numerous committee and official assignments include directionships of the Central Bank for Cooperatives in Washington and the Federal Land Bank of Louisville, and membership on the Board of Trustees of Berea College. His influence on agriculture will continue indefinitely through provisions in his will for financial encouragement to education and research in this field.

Ill health robbed Dean Cooper of active participaiton in his profession after he was relieved of administrative responsibilities. His illness and death mean that agriculture has lost an able servant, and those who knew him have lost an esteemed friend and wise counsellor.

He is survived by his widow Essie B. Cooper, his daughter Mrs. Catherine C. Hammond and two grandchildren, all of Lexington, Kentucky.

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DANA G. CARD

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REVIEWS

Mathematical Economics, R. G. D. Allen. London: Macmillan & Co. Ltd., 1956. Pp. xvi, 768. $10.00.

Twenty years ago, R. G. D. Allen published *Mathematical Analysis for Economists.* It is still one of the most useful books available to anyone who wants to learn analytic geometry and calculus for the purpose of working with economic theory. A few remarks about it will help to provide perspective on his new book, *Mathematical Economics,* which is the real subject of this review.

Allen's earlier book begins with about 100 pages on traditional analytic geometry for functions of one variable (that is, functions that can be graphed in two dimensions, one for the variable and one for the value of the function). In the next 170 pages or so it develops the ideas of limit, continuity, and derivative, and sets forth the differential calculus of functions of one variable, including maximum and minimum problems. The next 120 pages deal with analytic geometry and differential calculus for functions of two or more variables. Here are treated maximum and minimum problems without constraints on the independent variables, and simple cases involving constraints (such as the problem of a consumer maximizing utility in a two-commodity world subject to given income and prices); here Lagrange mutipliers are introduced. Then about 60 pages are devoted to integral calculus and differential equations. Following are about 80 terse pages concerning ordinary and constrained multivariate maximum and minimum problems, including the apparatus needed to check second-order conditions, i.e. Taylor series in several variables, determinants, and quadratic forms. The book closes with a short chapter on calculus of variations. It is an admirable book, and anyone who has mastered it has made a good start toward the mathematical competence needed for modern economic theory.

There are several areas of mathematics, treated only lightly or not at all in Allen's earlier book, that have become important for mathematical economics in recent years. Chief among these, in the reviewer's opinion, are differential and difference equations, for use in dynamic models; vector and matrix algebra, for use in systems of linear relations (which have a much wider application than might at first thought be supposed, particularly as approximations to nonlinear systems); and the algebra of inequalities and the theory of convex sets, for use in linear (and nonlinear) programming and the theory of games.

These topics in mathematics, and a large amount of mathematical economics making use of them, are the subject matter of Allen's new book, *Mathematical Economics.* His two books together cover the parts of mathematics that, in the reviewer's opinion, are likely to be most useful to

mathematical economists in the next generation. They do it in a way that can be followed by a person who is essentially an economist rather than a mathematician, provided that he is willing to invest the equivalent of about 20 per cent of a full-time graduate student's course load for a year on each of the books.

Allen's new book can be divided into three parts, corresponding roughly to the three topics mentioned above. The first part deals with dynamic models, using differential and difference equations. It contains nine chapters and about 300 pages. The second part deals with linear static models, using vector and matrix algebra. It contains five chapters and about 200 pages. The third part deals with game theory and linear programming, using the algebra of inequalities and the theory of convex sets. It contains five chapters and about 200 pages. There is a short last chapter on aggregation problems, which is essentially a summary of Henri Theil's book, *Linear Aggregation of Economic Relations* (North Holland Publishing Co., 1954). At the end there is a brief appendix on the algebra of operators, particularly the operators that take the derivative, the first difference, and the lagged value of the variable to which they are applied. There are also solutions and hints for the solution of the many exercises, a feature that makes independent study with the book easier.

The first three chapters present very simple dynamic multiplier and accelerator models that can be handled without much formal apparatus, using either lags of one period only, or first derivatives only. Here Allen exemplifies and discusses the several features that all his dynamic models have in common, and illustrates the kind of problem for which formal mathematics is required. The next three chapters are almost purely mathematical; they discuss complex numbers (which are important in solving difference equations), linear differential equations, and linear difference equations. The next three chapters discuss dynamic economic models using these techniques. Included are the multiplier-accelerator models of Samuelson and Hicks, trade cycle models of Goodwin, Kalecki, and Phillips, and some discussion of the engineering approach to servomechanisms and closed-loop control systems.

Allen says in his preface (p. v) that one of his aims is to give some synthesis of the "new" (largely Keynesian) economics. The economics in the first part of his book is disappointing, and particularly so in the light of this expressed aim, because the macroeconomic models he deals with embody relatively crude "Keynesian" economic ideas. For example, he uses consumption functions that depend only on income, ignoring the effect of wealth (the Pigou effect). He uses a liquidity preference function that has money illusion, i.e. that makes the interest-elasticity of demand for real balances depend on the price level even when initial levels of real balances and real income and interest are specified. He devotes only two

lines to Patinkin's work (p. 38), noting that Patinkin has raised "some basic objections" to certain macro models in the literature, but then he goes ahead and ignores the effect of the price level on total demand, thus getting the kind of model that Patinkin has shown to be untenable. For these and similar reasons, the first part of Allen's book is a good place to learn mathematics useful for dynamic economics, but it is not a good place to learn the economics.

The second part of the book concerns production functions and general equilibrium theory of the classical marginal type, and also of the more recent discrete type used in input-output analysis and linear programming. Input-output analysis, both the open and closed systems, and the extension to dynamics systems are briefly discussed. Three mathematical chapters on the algebra of vectors, matrices, determinants, quadratic forms, linear transformations, linear dependence, linear equations, and the like follow. From these three chapters the reader can get a good working knowledge of matrix algebra and related topics, and do it as easily as from any source the reviewer knows. Allen has a helpful way of filling in material that is usually left between the lines for the reader to get by himself. For example, he gives a most intelligible (to a novice) account of the Σ notation for summation (pp. 395-98). Also, the discussion of matrix operations is very detailed and good (pp. 403-34). However, the unity of the material is not as evident as it would be if presented in a more formal and systematic way, as modern mathematics texts do.

The third part of the book deals with game theory and linear programming. Chapter 15 gives a good discussion of two-person zero-sum games. Chapter 16 discusses linear programming, including the dual problem, the equivalence of the general programming problem to an appropriately chosen two-person zero-sum game, and the simplex method for solving linear programming problems. Chapters 17 and 19, respectively, deal with the use of linear programming in the theory of resource allocation, behavior of the firm, and utility theory. These last three chapters present the classical marginal analysis very briefly, and contrast it with the linear programming approach. In chapter 19 on utility theory, almost no use is made of the revealed preference approach.

The book contains some slips. For example, in defining a linear combination on page 385, Allen neglects to state that not all of the coefficients are permitted to be zero. The scalar product of two vectors is defined on page 381, and the inner product on page 396, with no notice taken of the fact that they are the same. There are at least a few others, and perhaps some undetected ones.

It is quite likely that this book will be widely used for some time to come, and justly so. The reviewer ventures to say that no other book will cover such a wide range in a way suitable for economists. However, it

will not have its field to itself to the same extent as did Allen's earlier book. Important new competitors include *Introduction to Finite Mathematics* by Kemeny, Snell, and Thompson (Prentice-Hall, 1957); *Modern Mathematical Methods and Models* (2 vols.) by the Dartmouth College Writing Group (including the three authors just mentioned), (Mathematical Association of America, 1958); *Linear Programming and Economic Analysis* by Dorfman, Samuelson, and Solow (McGraw-Hill, 1958).

CARL F. CHRIST

University of Chicago

Towards a More General Theory of Value, Edward Hastings Chamberlin. New York: Oxford University Press, 1957. Pp. xii, 318. $5.00.

In four new and 12 reprinted essays, Chamberlin seeks to develop the theory of monopolistic competition beyond the stages reached in his *Theory of Monopolistic Competition* (1933; 7th edition, 1957) and "to answer criticisms and to correct misinterpretations." Among the subjects he furthers are economies of scale, an experimental imperfect market, nonprice competition (three essays), the monopoly power of labor, welfare economics, and measuring the degree of monopoly and competition—including a rigorous and critical look at cross-elasticity. Among the criticisms to which he replies are those by P. W. S. Andrews and others on "full-cost" pricing; Harrod, "The Chicago School" (Knight-Friedman-Stigler *et al.*); and Mrs. Robinson.

As the book's title essay indicates, the unifying main purpose is to emphasize the generality of the theory of monopolistic competition. "It seems to be generally agreed . . . that the actual economic system is . . . a continuum [between the extremes of pure competition and pure monopoly]. There would seem to be a strong presumption that a theory which recognizes this must be more successful in explaining the system than one which does not." (p. 5) Monopolistic competition, therefore, is not limited to any one specific market structure, and in particular not to "large numbers, differentiated product." In fact, Chamberlin believes, "In the real world the most common case is certainly 'differentiated oligopoly' . . . ." (p. 33) It should be noted that his criterion for oligopoly is "merely nonisolation" (p. 87) and includes but does not require circular interdependence, let alone a particular *outcome* of circularity. This, again is very general.

Even the busiest economist should take time to read at least the essay "Monopolistic Competition Revisited" (substantially enlarged from the version published in *Economica* in 1951). This is a most lucid and compact presentation of the theory—it will be excellent for teaching purposes—and it would be foolish to try to compress it into still fewer words here. However, the essence of the Chamberlinian vision is this: Strictly consid-

ered, there is no more justification for ignoring the differences between the "products" of two *firms* than there is for ignoring those between the broader classes of products traditionally identified with two distinct and purely competitive *industries*. As scientists, we can no more ignore—still less can we berate—buyer preferences for Alpha Tomato Juice or for Omega brand than we can mentally blend tomato and pineapple juice into a homogeneous category "juice." In practice, heterogeneity arises partly by the nature of the products (through such production and selling characteristics as location, economies of scale, etc.) and partly in response to a demand for variety from buyers (owing to income, tastes, and location). (See p. 19) The preferences may be strong or weak; they may be "rational" or "irrational" (so may preferences between tomato and pineapple juice); they may be temporary or permanent. In particular, greater knowledge may cause customers to regard two products *either* as better *or* as less acceptable substitutes than they originally ranked them. Thus, monopolistic competition does not disappear in the long run, as Harrod, Bronfenbrenner and others have contended.

As for welfare economics, "If firms have demand curves of finite elasticity, these curves must play a part with cost in defining the welfare ideal, just as such demand curves for broader commodity categories play their part in conventional welfare theory." (p. 295) However, it is easier to reject pure competition as the welfare norm than to construct an improved set of standards, as recent explorers of "workable competition" have discovered.

Generality has its costs. Like that contemporary product variation, the sack dress, a theory designed to cover all cases will obscure the individual details of each. And critics of Chamberlin's approach will ask, "If 'anything can happen,' how can you use the theory for prediction?" Judging by the arguments on pp. 304-5 and elsewhere, the reply might be "Any theory has to be adapted to particular cases. But it would seem preferable to restrict the possibilities by empirical observation than to close them off a priori by selecting a narrow kind of theory." Chamberlin appears to show little enthusiasm for market classification as a compromise approach.

For nonspecialists the frequent textual citations are perhaps too minute, and certain of the papers may seem excessively polemical. However, when one notices the astonishing number of criticisms that have originated in plain ignorance of the theory, one can understand why they are there. Anyhow, Chamberlin enjoys doctrinal controversy, and the opening paragraph to "On the Origin of 'Oligopoly'" is one of several proofs that his good humor remains intact.

HOWARD H. HINES

Iowa State College

Agricultural Adjustment Problems in a Growing Economy, Earl O. Heady, Howard G. Diesslin, Harald R. Jensen, and Glenn L. Johnson, Ames, Iowa: The Iowa State College Press, 1958. Pp. xi, 315. $3.95.

This book includes the papers presented at a conference on agricultural adjustment problems sponsored by the North Central Farm Management Research Committee in cooperation with the Farm Foundation. The papers presented at the conference are divided into six major sections: 1. Setting of the Problem, 2. Demand and Supply, 3. Adjustments Related to Agriculture, 4. The Labor Resource, 5. Public Programs, and 6. Goals and Values.

Most agricultural economists are ready to admit that something is wrong with agriculture and that it needs correcting. This is the thought that the planners apparently had in mind because, as stated, the "basic purposes of the conference were to: (1) outline what already is known about adjustments needed in agriculture and solutions to the adjustments problem, and (2) develop promising hypotheses, concepts, and empirical techniques which can prove useful in further solution of the scale, resource use, and supply and income problems of commercial agriculture."

The papers devoted to the summary and analysis of the existing situation in agriculture and the basic forces which have given rise to it are excellent. The existing situation is described as primarily one of relatively low income for most farm families, and the culprit is technology. Both of these are examined with care and objectivity. An interesting feature of the book is an analysis of the effects of research and education on technological change, and a search for means of allocating research funds so as to improve the chances of reaching desirable goals for agriculture. Another is the presentation of what appears to be a rather remarkable insight into the theory of fixed assets and their influence on adjustments in agriculture.

Because the demand function for agricultural products has considerable bearing on the adjustments required to achieve improved income in agriculture, a section of the book is devoted to it. These papers are forthright in their two major points: (1) predicting total demand is difficult and tricky because we cannot predict its two major determinants: income and population, and (2) most efforts to expand per capita consumption of food are probably useless.

The adjustments problems of agriculture in an expanding economy are quite thoroughly covered. It is presumed that the U.S. will continue to grow at least at its recent remarkable rate so the concepts of growth and adjustment both receive emphasis. One contribution of the papers is to point out that economists have no thoroughgoing theory of economic growth which can be used in predicting supply and demand, and that this must receive greater attention in our research. Possible adjustments for

agriculture such as changing the product mix of the industry, efficient family-sized farms, and attracting outside capital are discussed, but for the most part the papers advise "adjusting" the labor force out of agriculture on the basis that to increase the price of labor it must become scarcer. For those who trust the future well-being of agriculture to the reduction in its labor force the book offers some very interesting papers on labor mobility and the potential for rural industrialization.

This book does a great deal to bring together the current picture of agriculture and the needs and possibilities for adjustments in the industry. Its main fault is more a matter of omission than anything else. With apparently one exception, each facet of the industry and its problems are looked at through the eyes of agricultural economists. This, no doubt, contributes to the continuity which the book has and makes it quite readable for agricultural economists, but it also makes for a more narrow view than would be true if other social scientists had been included, especially since major concerns of many of the papers are the farm people, their mobility, and their values. No conclusions are reached in the traditional sense because each of the participants prepared a more or less self-contained discussion of a restricted area. Moreover, no comprehensive agricultural policy program is presented as a result of the conference. The participants appear ready to admit that present and past programs have many faults because of the complexity of the problems and that rather than developing yet another proposal out of present knowledge they preferred to get on with the task of examining in some depth the research that is needed in production economics, labor mobility, human values, and so forth to help attain a workable policy. Although this book is aimed at the workers in farm management research and extension, there is no doubt that it can be used rather effectively in courses in agricultural policy.

WILLIAM F. HENRY

University of New Hampshire

Multiple Pricing of American Wheat (Present System Versus Two-price Plan), Helen C. Farnsworth. Stanford: Food Research Institute, 1958. Pp. 50. $1.00.

The merits of multiple pricing of wheat are examined by the author and found to be inadequate. Virtually the entire report is devoted to a demonstration of this conclusion. Sub-headings are listed as: (1) Size and Origin of the World Wheat Surplus; (2) Administrated Multiple Pricing under the Present Program; (3) Multiple Pricing Under the Proposed Domestic Parity Plan; and (4) Some Comparisons and Conclusions.

The first sentence indicates that "of our leading commercial crops, none is in a more unbalanced demand-supply position than wheat." The fault

is attributed to "high" prices, ineffective production controls, and technological advances. But most of all, high prices. The solution–lower prices, although the assumed effectiveness of this solution is not demonstrated.

In light of the recent vote in Congress relative to legislation including a two-price plan for wheat, this review could largely be academic. However, it might be useful to consider some of the elements of a two-price plan because the question is almost certain to arise in the future. For the same reason it might be well at this time to comment on the Farnsworth monograph.

This review has been especially difficult because this writer shares many of the opinions expressed in the monograph. However, by failing to deal with several pertinent problems and the inclusion of several questionable assumptions, the general position is weakened.

The reason why the two-price proposal is so hardy is that it stems from protection and subsidy offered different segments of the economy in different degrees. Development of power groups, enabling those groups to obtain economic advantage through tariffs, government subsidies, permission to engage in industry wide bargaining, etc., is a fundamental factor. Proponents of two-price plans for wheat see industries receiving protection from competition by foreign producers. If these foreign producers could engage in free trade, they might become paying customers for United States wheat. This protection is in the domestic market and its examples are legend.

A key issue thus centers around the notion that if wheat growers must purchase on a protected market they have a right for effective protection in the same market. Clearly, the social consequences of commerical practice embrace a much broader area than economics. As one reads Farnsworth's monograph, the question continually arises, why was this subject not dealt with since there was no hesitation in pronouncements of right and wrong, good and bad, fair and unfair.

In the preface the author points out the difficulty of analyzing anticipated effects of untried government programs because conclusions must unavoidably rest on many uncertain assumptions and judgments. The reader will not have far to look for illustrations.

For example, an implied assumption is that land, normally used to grow wheat, should not be shifted to other crops.

A judgment is that the United States should avoid the practice of "dumping" in international trade. Unfortunately this practice is not defined. Hence, it can be blamed for all sorts of ill effects when appropriate definitions are supplied.

Did Canada "dump" wheat after World War II in fulfilling its contract with Great Britain at prices well below world levels? During a part of

this immediate post-war period price ceilings prevented United States farmers from obtaining "world prices." Was the United States "dumping" wheat?

The author points towards additional price burdens borne by domestic consumers as the result of "high" wheat-support prices. She also credits the program for a part of the technological improvement in wheat production. The drive to reduce costs as a factor in technological improvement is not given much credit. How much better or worse off is the consumer on balance by way of these counter forces is not indicated. Without technological improvements induced by "high" price supports, could not the consumer be paying more for bread in the market place than the sum of the price of bread plus added taxes? If so, the consumer may be better off than had there been no program.

What is a "just price" when segments of an industry are controlled largely by monopoly elements? Virtually every decline in wheat prices since World War II has been absorbed in higher marketing and processing costs. Should wheat farmers imitate labor unions and industrial concerns by limiting the production through private organizations? Who will sponsor legislation permitting uncontrolled bargaining for prices by wheat growers? If higher wheat prices will increase bread prices, why have not lower wheat prices resulted in lower bread prices? If the surplus problem is solved, what is the prospect for higher bread prices absorbing savings to consumers in the amount of taxes now paid to support wheat prices? Again, it is regretted the author did not deal with these problems.

It is unfortunate that the United States and the USSR are linked as the two outstanding examples of government price fixing for agricultural products on a "welfare" basis, thus possibly implying that two-price proposals merit no further consideration for this reason. Is guilt by association an appropriate tool for economic analysis?

In summary, the reader will find in this monograph data indicating many wheat prices in the world where virtually all markets are controlled by government agencies. Interesting comparisons of utilization and exports are presented as are data showing the development of the present situation of world surplus. However, the reader will discover important issues are omitted.

The title indicates the contents will compare the present system and the two-price plan for multiple pricing of American wheat. This format is followed in parts of the monograph and is not followed in other sections. As a result, some problems are superficially handled which could best be handled under a different title.

Finally, the reader will detect an undercurrent of antagonism towards wheat farmers. This is both reassuring and disconcerting. It is reassuring to feel the author's well-known analytical skills are not directed toward

becoming an industry spokesman. But it is disconcerting to feel perhaps the author attempted to display only one side of the issue.

In general, it is the reviewer's opinion this monograph falls short of what we have become accustomed to associate with the Food Research Institute and the previously demonstrated capabilities of the author. It will not provide an example of her best economic analysis although in view of the general impact already felt in the area of wheat price policy it may well turn out to be a classic in persuasion.

LEONARD W. SCHRUBEN

Kansas State College

Multiple Purpose River Development, John V. Krutilla and Otto Eckstein. Baltimore: Published for Resources for the Future, Inc. by the Johns Hopkins Press, 1958. Pp. xiv, 301. $4.50.

Krutilla and Eckstein have written an important book in water resource policy. An analytic treatment of this subject in book form is needed. Such a book is a good supplement to those dealing with the institutional and engineering aspects of water resource development.

In describing their treatment the authors state in the preface, ". . . it is hoped that this combination of experience and training will result in much which is new—or presented in a new perspective—not only to economists and other professionals engaged in the field of water resources, but also to all serious students of issues in this area. In addition, one particular aim has been to prepare useful working material for upper-division or first-year graduate students in applied economics or conservation curricula sponsored by numerous universities for education in the field of natural resources" (p. v). And in the final chapter entitled, "Conclusions and Policy Implications," they state, "First, we have clarified to a substantial degree the factors which must be taken into account to achieve economic efficiency, a relevant consideration in public decisions relating to water resources development. Second, where "higher criteria" are given major weight, the type of analysis which we have illustrated provides a means of determining what is the economic cost to society of realizing such intangible values" (p. 266). It appears to this reviewer the authors' evaluation of their own work should be taken at face value except for rather minor qualifications.

Part I of the book deals with concepts and methods, while Part II applies the analysis to three selected case studies. Much of Part I is a review of the familiar efficiency criteria of welfare economics. The deviations that occur in the field of water resources from the assumptions of the model are noted. Much of this material is old stuff. Although the presentation is competent, it is not especially imaginative, ranging from the elementary concepts of economics to the moderately complex in relatively

few pages. The professional economist will have no trouble with this and may be a bit bored; the noneconomist may find it tough sledding. However, chapter IV entitled, "The Social Cost of Federal Financing" is excellent. In this chapter an attempt is made to estimate the opportunity cost of federal funds used in constructing water resources projects. The conclusion "if an efficient allocation of resources is the criterion, only those public investments than can produce a rate of return equal to the opportunity cost—or a rate of 5 to 6 per cent—should be undertaken" (p. 125) obviously depends upon assumptions. These assumptions regard the level of employment, the distribution of income, the acceptance of the time preference of the present generation of decision makers, the tax rate, and others. But a model has been provided and other assumptions could be used if they were thought to be more appropriate. However, the logic of using opportunity cost rather than the government borrowing rate is, to this reviewer, without question. The contribution is that an estimate of the opportunity cost can be made. Of course the estimate should be checked under different assumptions, but this is a pioneering effort and as such needs to be commended. The practical significance of this is that many of the government-sponsored projects which now have a benefit cost ratio greater than unity would fail to qualify as being economically feasible if the opportunity cost rate were used.

Part II treats the Hells Canyon case and the Alabama-Coosa River system by analyzing the efficiency effects of development by different parties. The Willamette River case traces through the income distribution effects of development by different parties where it is assumed the efficiency is the same.

The reviewer has mixed feelings about the Hells Canyon and Willamette River treatments. He is not familiar with the Alabama-Coosa situation, and therefore has no comment to offer. In the Hells Canyon case the discovery that a two-dam system would be superior, on the basis of efficiency criteria, to either the Idaho Power three-dam system or to the Army Engineers High Hells Canyon is revealing. However, a number of other alternatives have been proposed so that the conclusions reached certainly should not be accepted as a final answer. (The authors recognize this in a footnote saying the results are "illustrative." p. 145) For example, the Oregon State Water Resources Board has evaluated 18 different alternatives from an engineering standpoint. An analysis of only three alternatives is, at best, partial. The Willamette Valley situation is also partially synthetic; again it is of value mainly for illustrative purposes.

However, these objections are minor. The authors have clearly separated the efficiency issues from other value-loaded problems. This is desirable. It permits arguments over facts to be separated from arguments over values. The book also directs attention to the relevant facts. The re-

viewer holds the belief that if we could agree on the facts we might then come closer to agreement on values. For example, if the materials on Hells Canyon that are now available had been developed earlier and widely disseminated, it is doubtful that Idaho Power would now be active in the Middle Snake constructing three "small" dams. Even some private power advocates have had their enthusiasm cooled considerably after recent investigations have been called to their attention. It now appears likely that there will be information to know, too late, that a mistake was made if resource efficiency is used as the criterion.

One should not draw the conclusion, however, that this is a "one-sided" book. Public project advocates will draw little comfort from chapter IV. The study results in institutional implications that, if recognized sooner, might have made the partnership approach more effective. The results of a pure efficiency study such as this can be used by decision makers in the political process. If politics had been brought into the analysis at an earlier stage, one would not know if the results were due to political expediency or efficiency considerations.

Some of the interesting theoretical and empirical parts of the book hinge on analyses made in Eckstein's forthcoming volume, *Water Resource Development: The Economics of Project Evaluation*, to be published by the Harvard University Press. Many readers of the book being reviewed will undoubtedly want to place an order for what almost appears to be a companion volume.

E. N. CASTLE

Oregon State College

Land Economics, Revised Edition, Ronald R. Renne. New York: Harper and Brothers, 1958. Pp. xiii, 599. $6.00 and $8.00.

Since most agricultural economists are familiar with the first edition of *Land Economics*, this review will be particularly concerned with revisions. Some attention will also be given to sections which were not revised but which, perhaps, should have been.

The revised edition includes 23 chapters divided into six major parts. Part I consists of two chapters and is entitled "The Field of Land Economics." The fields of land economics and farm management are differentiated in relation to their strategic or limiting factors, which are given as land and management, respectively. This distinction has little meaning because the study of land economics, as well as the study of farm management, is concerned with problems of managing land and the associated resources. The important distinction between these two overlapping fields is found in their orientation; that is, farm management is oriented toward the individual firm while land economics is oriented toward the public. This reviewer, who believes that macro and micro economic problems

are quite distinct both as to nature and solution, would have welcomed a stronger differentiation on this basis.

In the second chapter two major problem areas in land economics are identified. The principal focal points of land economics, since the turn of the century, are given as: (1) problems in the conversion of land from one major use to another general use, and (2) problems in the attainment of land tenure objectives. Both problems are said to arise from social change. That problems in these areas are real, and perhaps paramount, few would argue. But that they have arisen solely because of social change is disputable. Quite likely, as is pointed out on page 43, inappropriate initial allocation of land among uses and among firms is an equally important source of unsatisfactory conditions.

Part II consists of six chapters and is entitled "Principles of Land Utilization." Chapter 3 on the supply of land is somewhat disappointing since it carries over from the first edition a labored distinction between the physical and economic supply of land. The economic supply of land is defined (page 28) as "the schedule of land units which will enter particular uses in response to price at a given time and a given place." The present economic supply of land is said to be "that which is now being used for all economic production." Implicit in these definitions is the assumption that land of all kinds and locations appears on one supply schedule. But even if this quite unrealistic assumption is granted, the definition of "present economic supply" refers not to a schedule but to only one point on a supply curve.

Since the concept of "supply" is treated quite adequately in most elementary texts in economics, further discussion of this point may be superfluous. On the other hand, those who use this book as a text should forewarn their students concerning confusing statements made in this chapter. For instance on page 29 is a statement which implies that the supply of land responds to price. As taught in economics "quantity supplied" not "supply" responds to price. On page 32, the statement is made that the discovery of an economic method of synthesizing food might conceivably cause the supply of agricultural land to become unlimited. The actual consequences of such a discovery could be that the "demand" for agricultural land would be destroyed. Conceivably, land presently used for agriculture, might cease to be an economic good. The consequences would not be a change in the supply of land.

The confusion in the concept of supply is further demonstrated and compounded on page 33. Six ways are given which will, the author asserts, increase the economic supply of land. This assertion is incorrect. None of the six actions listed will increase the supply of land. Three of the items refer to the investment of other resources into land. Two of the items indicate ways in which the demand for products of the land might

be modified or reduced. One item refers to the shifting of land between countries by military conquest.

In Chapters 7, 8, and 9, the author attempts to set out the economic principles which guide the allocation of land resources and distribute the income from the land. Little is accomplished in these chapters; but perhaps such an effort is necessary in a book intended for use as an introductory text. Unfortunately, in these chapters and in some other sections of the book the implication is given that price and profit are the only, or at least the principal forces which can be depended upon to cause unused land to be developed or to engender changes in land allocation. But relatively few of the major problems of malallocation or underdevelopment will be solved in response to market forces. On the contrary, many of these problems have arisen precisely because of the actions of individuals responding to the profit motive. This criticism is not to imply that the author is not fully aware of this fact, but instead is intended to point out that a great many readers need to be reminded of the frequent conflicts between public and private interests. The author treats this point on page 185 but has failed to integrate the idea into much of the material. Nor, for that matter, has the economic theory in chapters 7 and 8 been integrated into the rest of the book.

Chapter 9 is an adequate treatment of the topic of land conservation. The author draws upon most of the better writers in the field. However, again the efficacy of the profit motive is perhaps overemphasized. On page 183 the statement is made that farm operators will conserve the soil only if it is profitable to do so. But nonmonetary motives such as pride in good husbandry and feelings of obligation to posterity quite likely account for much conservation activity. This chapter does serve a good purpose since most of the economic terms related to conservation are well defined and illustrated.

Part III consists of nine chapters and is entitled "Land Income and Value." This section has no counterpart in the first edition although several chapters revised from the first edition are included here. Within rather severe space limitations, the topics of land rent, land values and appraisal, mortgage credit, land taxes, and land tenure and tenancy are reasonably well treated. On page 258, in the description of the Farm Credit Administration, a farm credit district is said to consist of three banks and the production credit corporation. This statement is in error since these corporations are now defunct and their functions are performed by the federal intermediate credit banks.

Part V entitled "Distinctive Features of Major Land Uses" is somewhat repetitious of material found in earlier chapters on land supplies and requirements for specific uses. However, these are some of the better

chapters in the book and incorporation of the material in the earlier chapters, rather than deletion, is indicated.

Part VI consists of two chapters, "Land Use Planning" and "Land Reform." The former is a much improved treatment of a topic covered in the first edition. The latter is an added topic which would be difficult to ignore, since it represents one of the pressing and difficult problems presently confronting the world. Furthermore, land reform is appropriately treated in conjunction with land-use planning because only with rapid public action will major uprisings be averted in many of the underdeveloped areas of the world. As implied by the author, unguided action of land holders will likely deter rather than facilitate land reform.

The first edition of *Land Economics* was widely adopted as a text for introductory courses in land economics. The revised edition, improved both as to content and organization, deserves, and will likely have, a similar reception.

LOYD K. FISCHER

University of Nebraska

Cooperative Independent Commission Report. Manchester, England: Cooperative Union, Ltd., 1958. Pp. xi, 320.

This report may be the most important book published on cooperatives in Great Britain since 1857 when George Jacob Holyoake's "History of the Rochdale Pioneers" began to appear in chapter form. This is not said to disparage such seminal works as "The Cooperative Movement in Great Britain," by Beatrice Potter (Mrs. Sydney Webb) (1888), or "Consumers' Cooperation in Great Britain," the able study by M. Carr-Saunders, P. Sargent Florence, Robert Peers, and others (1938).

The present report differs from these books in that it deals with the consumer cooperatives of Great Britain at a time of impending crisis. Can they meet the challenge of change? *The Economist* which aptly reviewed this book under the title, "Can the Co-ops Compete?" opened with this sentence, "A movement born in social aspiration is losing ground in an epoch keynoted by social progress." Consumers' cooperation in Great Britain is not small business. It is a broadly integrated cooperative system of over a thousand retail societies, with over 12 million members. These societies own over 30,000 shops, and sales reach nearly one billion pounds a year. They own and are served by 250 factories providing a wide assortment of products and two cooperative wholesale societies doing a volume of 500 million pounds annually. After recapitulating these facts, *The Economist* (London) simply said, "This gigantic complex is showing unmistakable signs of decline."

The weakening of cooperative momentum began to be apparent in the forties, but it was masked by the inflation, World War II, and the early

post-war period. In the last several years it has been obvious that the trend must be reversed if cooperatives are to maintain their position or improve it in the years to come. Recognizing the seriousness of the problem, the Cooperative Union Ltd. (the policy-formulating body of the cooperative societies) in 1955 set up "An Independent Commission of suitable persons not engaged in cooperative management or administration," charged with "the responsibility of surveying the whole field of cooperative production and marketing, both wholesale and retail," and of reporting its findings and recommendations to the Union prior to its 1958 Congress.

The commission of "suitable persons" was composed of:

H. T. N. Gaitskell, economist, former Chancellor of the Exchequer, and leader of the Labour Party

Margaret Digby, secretary of the Horace Plunkett Foundation, and a recognized authority on agricultural cooperation

Professor D. T. Jack, Professor of Economics, Durham, and arbitrator in labor disputes

Dr. J. B. Jeffreys, economist and secretary of the International Association of Department Stores

Colonel S. J. L. Hardie, founder of British Oxygen, and formerly Chairman of the National Steel Board

Mr. J. T. Murray, cotton trade and industrial consultant

Alderman F. Pette, formerly manager of Middlesborough Co-operative

Lady Margaret Hall, economist and authority on retailing, Somerville College, Oxford

Mr. Gaitskell served as chairman, and C. A. R. Crosland, the well-known economist, served as secretary. He, more than any other, is given credit by the commission for the execution of the mission and the preparation of the report.

The report is divided into five parts: Diagnosis and Principles; The Retail Movement; The Cooperative Position; Production and Wholesaling; and Conclusions and Recommendations.

It is not possible to adequately summarize this comprehensive analysis in a few paragraphs. It is an incisive, closely reasoned thesis which admittedly "tends to concentrate on what is wrong rather than what is right, and to place the emphasis on the unfilled potentialities rather than the progress already made." Its findings thus will not be popular with established cooperative interests and those that prefer sentiment to fact.

The general theme of the report is that there must be a change of emphasis—to recognize the growing importance of integrated retailing as

reflected in the rapid growth of multiple-store systems. To meet this problem a national federal society to be known as the Cooperative Retail Development Society is proposed. This body would "reinforce the operations of the local society by initiative from the center."

The Co-operative Retail Development society would not be a trading federation which would closely control its retail members. It would confine itself largely to promoting reorganization and expansion. The broad recommendations of the report make its function clear. On the retail side, they call for a program of expansion, involving amalgamation, better use of finance and more modern management; while on the wholesale side, they call for reorganization in terms of planning, concentration of effort, and a new managerial structure. The Retail Development society is a means to these ends.

The report is not defeatist; it simply looks at the problem of consumers' cooperation in Great Britain with a clear, cool eye. The way out, or the way up is clearly indicated. The problem that remains is whether the medicine will be taken while there is still time.

The discussion in the report on problems of management, organization and finance is concise and penetrating, and the tone of the report is that of a competent and friendly physician who seeks to re-establish the health of his patient, through hemeopathy, surgery and psychology.

There is much in the report of value to American students of cooperation. The problems presented are not those of British cooperation alone. They are the problems of many democratically-owned and controlled cooperative societies, and they call for patience, understanding and decision.

JOSEPH G. KNAPP

Farmer Cooperative Service

Japan's Economic Recovery, G. C. Allen. London, New York and Toronto: Oxford University Press, 1958. Pp. xi, 215. $4.75.

Japan's Postwar Economy, Jerome B. Cohen, with a foreword by John D. Rockefeller III. Bloomington: Indiana University Press, 1958. Pp. xvii, 262. $6.50.

These two books, the first written by an outstanding British authority on Japan's economy, and the second by a younger American counterpart, present an unusually interesting comparison. Both are essentially updatings of earlier detailed and scholarly analyses of Japan's economic and industrial structure and development. Completed within six months of each other, carrying almost identical titles, of almost the same size and scope, having approximately the same objective, using many of the same sources, and intended for parallel audiences on the two sides of the Atlantic, they appear at first glance to be mere substitutes for one another.

On the contrary, they complement and supplement each other, and they can be read together with profit.

Both books are concerned with a review of Japan's economic recovery since the war, an analysis of unsolved problems, and an assessment of Japan's future prospects. Both record in detail the astonishing strides made by Japan since 1945 in rebuilding her industry and revitalizing her society, and in recapturing her position as Asia's foremost industrial and trading nation.

Both note the severity of her unsolved problems. Population pressure, already greater in relation to total natural resources than almost anywhere else on earth, continues to mount. Latent unemployment, now partly disguised by a large supply of underemployed labor in agriculture, constitutes a continuing threat to political stability. Tensions resulting from the enduring dichotomy in the economy between a modern and increasingly productive large-scale industry on the one hand, and a peasant agriculture and relatively primitive small-scale industry on the other, persist.

In a world in which trading relations are highly unstable and uncertain, Japan must depend increasing on trade to meet her substantial deficits in food and raw materials. Her prewar exports consisted primarily of labor-intensive consumer goods, especially textiles, in which she had and continues to have a cost advantage over most of the rest of the world. The loss of export markets for her silk to synthetic substitutes, and the more recent reduction in her cotton textile trade, have led to a new emphasis on export of capital-intensive heavy industrial goods. To support this type of export she must import, often at great cost, an increasing proportion of the necessary raw materials. Her competitive position in world markets is thus less secure than it was when her trade was based on textiles.

The writers agree that Japan's raw material problem could not be readily solved by opening up trade with China. The reorientation of China's trade away from Japan and the West and toward the U.S.S.R., coupled with domestic industrial development in China and Korea have changed the nature of Japan's trading relation with the mainland. The immediate potential of this trade appears to be far less than the level wistfully assumed by a number of Japanese businessmen and political figures.

The two writers pay tribute to Japan's ingenuity, vigor, adaptability, and demonstrated skill in surmounting apparently insurmountable obstacles in the past, and both find grounds in these qualities for a cautious optimism about Japan's capacity to meet apparently overwhelming problems in the future.

Although the findings and conclusions of the two books are similar in many details as well as in relation to larger issues, certain important differences in focus, emphasis and approach should be noted. Allen has made an historical and institutional as well as an economic analysis of

the forces that worked the changes in Japan's economy in the postwar period. He draws for the reader an outline picture of the social, cultural and institutional roots of present day Japan, and places his rather extensive statistical discussion of current economic patterns in this setting. The present is thus seen as part of a stream of cultural, economic and political history.

At the risk of appearing to underrate Cohen's obviously useful and valuable contribution, this reviewer would characterize his book as a statistical description of the results of the forces analyzed by Allen. Cohen makes extensive statistical comparisons between the prewar and postwar periods, and he occasionally traces the roots of individual institutions with which he is concerned. But he does not describe, and this reviewer is inclined to suspect that he does not fully appreciate the social fabric of Japan. Allen's approach lends a richness and depth to his analysis that is largely lacking in Cohen's. It also permits Allen, writing from longer and more intimate personal experience with the people of Japan, to achieve greater perspective on the way in which the Japanese organize their life, their economy, their businesses and their technologies. Japanese patterns of organization differ in many respects from American and Western methods. Many Americans, including possibly Cohen himself, tend to dismiss Japanese ways as inefficient partly because their relation to a different social context is not clearly comprehended.

For example, Allen, in discussing the structure of Japan's sewing machine industry describes a "cooperative system of production" involving extensive subcontracting, and notes that "As in the other branches of the Japanese economy, this combination of large-scale organization at the centre with a wide diffusion of the actual processes of production led to the emergence of a highly efficient industry." (p. 108) Cohen does not mention this method of organization in relation to the sewing machine industry, but in general he appears to dismiss it as "excessive subcontracting" (p. 127). To Cohen it presents a barrier to the development of efficient industry, because "obviously the ability to modernize is largely confined to the larger firms—some 6 per cent of all Japanese manufacturing enterprises—since the other firms are too small to attract capital or to have access to newer techniques and newer equipment." (p. 80) Cohen does not consider the possibility that the subcontracting technique may be a bridge between small-scale and large-scale industry that makes possible the use of existing plant and skills under conditions of capital shortage, and that it may provide a channel rather than a barrier for the flow of capital and improved technology to the smaller firms.

If Allen's contribution lies in the historical and cultural perspective brought to bear on the subject, Cohen's lies in a detailed, authoritative statistical analysis of specific economic and industrial changes. As in his

earlier books on Japan's economy,[1] Cohen demonstrates an extraordinary capacity to breathe life into a recital of statistics. This is a literary gift of no mean proportions. When handled as well as in the four chapters on Japan's trade problems, it fully compensates for the lack of historical and social perspective. These chapters are the best in the book, and in many respects are superior to Allen's parallel treatments. Together with the chapters on income, output and employment, the changing industrial structure, and the fight against inflation, they comprise the heart of the book and the bulk of Cohen's contributions.

His chapter on agriculture, entitled "People and Food," is less successful. Cohen does not cope with agriculture's problems with the same sure hand that he applies to the problems of industry and trade. In this area Allen's analysis is substantially more successful than Cohen's.

If criticism is to be levelled at Cohen's generally excellent statistical treatment, it is that he displays an occasional tendency to draw, without warranted qualifications, uncritical inferences from statistical aggregates. This is a tendency that was present in his earlier work, and while less conspicuous here, still appears.

One could also carp about an associated tendency to make rather loose and inadequately substantiated statements about cause and effect, especially in the discussion of agriculture. Most of these are insignificant but one referring to the effect of the Japanese land reform program on size of farm units deserves special comment. Cohen makes the statement (page 30-31) that "while the growth of population in relation to the limited supply of arable land was undoubtedly a factor in reducing the average size of the Japanese farm, the main force was in all probability the land reform program begun in late 1946." He then outlines the objectives and accomplishments of the reform. On page 33, he resumes his evaluation of the program with the statement: "In part as a result of the reform, the number of very small farms (less than one hectare) rose from 4,018,748 in 1946 to 4,293,100 in 1955. As compared with the 3.4 million farms of less than one hectare existing in 1941, there are now almost one million more of this tiny size." A reader of this passage would be led to attribute a large part of the blame for this highly undesirable trend to the land reform program.

As one who had a part, however small, in the administration of the land reform, this reviewer cannot let this statement pass without comment. A closer look at the statistics cited is revealing. A quick calculation based on the passage quoted above shows that between 1941 and 1946, the

[1] *Japan's Economy in War and Reconstruction*, with a foreword by Sir George Sansom, Minneapolis: University of Minnesota Press, 1949, 545 pages, and less notably in his shorter and much more superficial *Economic Problems of Free Japan*, Princeton: Center of International Studies, 1952, 96 pages.

number of small farms increased about 18 per cent. The first purchases under the land reform program were consummated as of March 31, 1947. Between 1946 and 1955, the number of small farms apparently increased about 7 per cent. The annual rate of increase after the reform thus appears to have much slower (about one-fourth) than that occurring before the reform. This comparison is probably overly favorable to the land reform program, for it ignores extraordinary pressures on agriculture in the immediate postwar period, such as soldier repatriation, that tend to distort the statistics. It is probably sufficiently justified, however, to illustrate the type of flaw that occasionally mars Cohen's work.

The reader may still ask why any increase in the number of very small operating units should have followed the reform. Two factors have been of particular importance in this connection. One of these was the growth of population pressure, noted by Cohen, but apparently placed in a minor role. The cure for this problem must be sought outside of agriculture and outside of land reform, in the creation of employment opportunities in industry for agriculture's surplus population.

The other factor was the abolition of primogeniture and the establishment of equal rights by all heirs under the new Japanese constitution adopted in May 1947. This measure has had a pernicious effect on agriculture because it has provided a legal basis, if enforced, for forcing the subdivision of already minute agricultural holdings. It was not, however, part of the land reform program. It was a general social and constitutional reform, applied to all sectors of the economy. Its purpose was destruction of the Japanese "household" system and reduction of the enormous powers formerly vested by law and custom in the heads of households. It was an essential element in the postwar program for democratization of Japan, but its compatibility with the long-range welfare objectives of the land reform program has been recognized since its inception. Solution has been complicated by the practical problem of finding a way to finance purchase of the rights of his brothers and sisters by the heir selected to run the farm as a unit.

In spite of these defects, however, Cohen as well as Allen has made a valuable contribution. As stated at the beginning, the student would do well to read them both. If this is impossible, readers interested in economic processes would probably prefer Allen's approach, while those desiring a reference work on accomplishments would find Cohen's more useful. To those without background and experience in Japan, Allen's book would be particularly valuable. Students who can for themselves place Cohen's book in its larger setting will find that it has much to recommend it.

DOROTHY C. GOODWIN

University of Connecticut

The Economics of the Fur Industry, Victor R. Fuchs. New York: Columbia University Press, 1957. Pp. vi, 168. $5.00.

Here is a fascinating picture of a unique and complex industry. Fuchs has done economic analysis a service in his exploration of the fur business from pelt to stole. Heretofore, most studies have concentrated on the highly documented, few-firm monoliths with large quantities of comparatively adequate data. This book should encourage more studies into industries that are unorthodox, with unusual demand and price problems, and into the intriguing areas of "conspicuous consumption."

Although this reviewer has some serious reservations about the approach and methodology of the statistical analysis, it is a valuable book. It should be of interest both to the economist and the serious general reader. Style, arrangement and format could serve as a guide to many writing in the social sciences today. The author definitely has talent as a literary economist. This is not patronization, but high praise. One has the feeling after reading this book that he understands and sympathizes with the fur industry, but is not able to evaluate the factors contributing to its operation in any significant quantitative sense. The subjective views are clear and comprehensive, the philosophical reasoning and conclusions seem sound, but the correlation and time series analyses leave one somewhat empty and frustrated. Data inadequacy should be emphasized, and here the reviewer has compassion.

In the preface the author states his hope to investigate two problems: the short-run instability and the long-run deterioration of the industry, and the general economic structure. It is truly a "labor of love," yet one of the most admirable characteristics of Fuchs is his willingness to make value-judgments in the areas touching on habits, customs and politics.

In the first chapter the writer carefully and interestingly defines his products and describes their sources. Imports, trapping and fur farming are discussed thoroughly. One of the attractive features of the industry is the way in which the firms change in degree of competition at the various stages of production.

Next the manufacturing processes are inspected. Dressing and dyeing comprises a few large firms, quite monopolistic in structure, that usually operate on skins owned by the dealers or garment makers. From a financial and economic standpoint these are the healthiest firms in the industry. The dealers fashion the final product and, in what might seem a marketing pandemonium, it moves out to the retailer, jobber or directly to consumer. Wages, other costs, labor relations and pricing problems are detailed in an informative and authoritative manner. The author's exposition and approach to short and long-run cost curves is the best empirical work in the book.

The study of consumer demand and fur retailing is disappointing. Granted that data are scarce and the response factors elusive, this reviewer feels that much of the methodology is questionable and the conclusions are shaky. The analyses do not include the competition effect of other apparel luxury items. Sales and income relationships for the years 1939 and 1948 might have been more meaningful if deflated or adjusted for income. Comparable series over time handicapped a dynamic analysis. However, in the two analyses for the years 1939 and 1948, using state data, his coefficients are not impressive despite the high R^2s. He relates per capita fur sales to per capita income, percentage of population urban, mean winter temperature and percentage of families with incomes over $10,000. This may be entirely a parochial criticism but there are no standard errors given, just the partial correlations. The latter are not impressive and the degree of urbanization and mean winter temperature appear to be the only important factors, although the others do have the right signs. The author's study on nonseasonal fluctuations is sometimes disjointed and obscure. The graphical exposition of patterns between fur sales and other economic indicators is somewhat punctured by the very modest correlation coefficients.

The final chapters on competitive structure and the suggestions for remedying a very sick industry are excellent. The author's sense of social and political realism is refreshing and unusual. His grasp and his ability to display the total organism by itself and then in relation to the rest of the economy is to be applauded.

WILLIAM W. ADDISON

Agricultural Marketing Service, USDA

L'Agriculteur à la conquête de son marché, Henry de Farcy. Paris: Spes, 1958, Pp. 490, 2,250 francs.

De Farcy is reporting on his studies of U. S. agricultural marketing. From an understanding of American accomplishments in this field he hopes that lessons may be drawn which will aid the French farmer.

Similarities are pointed out in the characteristics of American agriculture before World War II and French agriculture in 1957, and perhaps the most important similarity is in having problems of surpluses. The author recognizes the difficulties of applying in France lessons learned in America and openly declares that he will not in this work attempt to advise how French farmers may adopt marketing practices that have been successful in the U. S. The book is mainly descriptive and even avoids the usual overtones of criticism that tempts so many French authors who write about America and so many Americans who write about France.

After a discussion of the marketing objectives of the American farmer, de Farcy divides his book into two major parts: Sales Promotion and

Collaboration of the Farmer and the State. Under Sales Promotion, using a case method approach, the author discusses such topics as Marketing Research, Advertising, and Public Relations. The second part of the book offers examples of sales problems which have called for government aid. The case studies in the book, run the gamut from how a roadside vendor increased his sales and how the American Dairy Association conducts its advertising campaign to a discussion of the Food Stamp Plan. As in a Harvard Business School text, most of the pages describe specific situations.

The last chapter concerns the application of American experience to French agriculture. Here an attempt is made to generalize about the American approach to marketing problems as contrasted to the French approach.

In appraisal, one should say that this is an extraordinary work, and just as useful to the American student as to the French. It is not a scholarly book, but it does have an excellent perspective on the American marketing scenes. De Farcy might have used a Gunther title like "Inside Marketing, U. S. A." but the book is much better documented and more complete than an "inside" book. The style is as readable and racy as a reporter's. It seems extraordinary that in one year of study in the U. S. A. the author could understand so much. In no other publication is all this material brought together and analyzed so clearly. Certainly French agriculturists will gain much insight from the book. Even Americans may see America in greater perspective. It takes frequently the quality of a foreign writer to understand a country better than the native. James Retson and Alistair Cook have set high standards for reporting on American politics and de Tocqueville has written one of the classics on America. De Farcy has done the job in U. S. agricultural marketing and for this reason some of his chapters are now assigned reading in the marketing seminar at Rutgers.

RONALD GATTY

Rutgers University

NEWS NOTES

CARL J. ARNOLD, Associate Professor in Agricultural Economics at Virginia Polytechnic Institute, received the Ph.D. degree in June from Michigan State University.

ROBERT C. ASHBY, Emeritus Professor of livestock marketing at the University of Illinois, died March 16 at Sioux City, Iowa. He had been on the staff for 22 years at the time of his retirement in 1949. He was on the staff of Morningside College from 1949 to 1956.

LUTHER ATCHLEY has joined the Washington staff of the Farm Economics Research Division, ARS, to work on the Potomac River Survey.

C. B. BAKER has been promoted to the rank of Professor at the University of Illinois.

GEORGE BAKER, on leave from Purdue, will spend this academic year on the staff of the Harvard Business School.

EDMUND BARMETTLER joined the University of Nevada staff as an Assistant Professor, after finishing work on his degree at Ohio State.

SHERWOOD O. BERG, Head of the Department of Agricultural Economics, University of Minnesota, spent August and September on an extended tour of universities in the Far East. He also attended the International Conference in India.

OSWALD P. BLAICH has been employed as a cooperative agent by the University of Minnesota and the Market Organization and Costs Branch, Marketing Research Division, AMS, to study the economic consequences of vertical integration in the production and marketing of livestock.

GEORGE T. BLANCH, Head of the Department of Agricultural Economics at Utah State University, Logan, left with his family for Iran in August to serve for two years as Advisor in Agricultural Economics at Karadj Agricultural College under contract with the ICA.

ROBERT BOCK has joined the staff at Purdue University as instructor in agricultural marketing. In cooperation with the U. S. Department of Agriculture, BOCK, C. B. COX, W. S. FARRIS, and JOHN DAY will produce educational materials and demonstrations for extension use.

ROY A. BODIN, State Statistician in charge of the St. Paul, Minnesota, office received the Ranelius Award of $50 at the annual convention banquet of the Turkey Growers Association in recognition of his service to the State's turkey industry.

RALPH BOTTS, Farm Economics Research Division, ARS, spent some time in May assisting officials of the Brazilian government in the discussion of acturial formulae for use in the crop insurance program in that country.

LAWRENCE A. BRADFORD, University of Kentucky, attended the Tenth International Conference of Agricultural Economists in Mysore, India. He was one of 10 agricultural economists from this country to receive a grant from the United States Finance Committee and Council to attend this conference.

EMERSON M. BROOKS, Agricultural Estimates Division, AMS, has received a superior service award "for developing operational procedures for the improvement of agricultural estimating methods and for conducting training programs for foreign nationals."

DAVID W. BROWN, Associate Professor and Associate Agricultural Economist,

University of Tennessee, has resigned to accept a two-year assignment as Visiting Professor at the University of Malaya in Singapore under the sponsorship of the Council on Economic and Cultural Affairs.

HAL F. BRYANT, State Statistician in charge of the Louisville, Kentucky, office retired in September with over 43 years of government service. His successor is JAMES M. KOEPPER.

MARGUERITE C. BURK, Head of the Consumption Section, Agricultural Economics Division, AMS, was one of the 50 winners of an essay competition sponsored by the Committee for Economic Development. She received a $500 award for her essay, "What is the Most Important Economic Problem to be Faced by the U.S. in the Next 20 Years?"

REX G. BUTLER transferred from Washington, D.C., Livestock and Poultry Statistics Branch, Agricultural Estimates Division, to the Harrisburg, Pennsylvania, office.

C. CURTIS CABLE, JR., has been employed by the Market Organization and Costs Branch, Marketing Research Division, AMS, to develop work in the marketing of fiber crops. He will be stationed at Tucson, Arizona.

WILLIAM O. CHAMPNEY joined the staff of the Department of Agricultural Economics and Rural Sociology at West Virginia University as Assistant Agricultural Economist, May 1.

VIRGIL C. CHILDS, State Statistician in charge of the Austin, Texas, office, retired in June with more than 37 years of government service.

WALTER CHRYST, Farm Economics Research Division, ARS, was in Lima, Peru, from July to October as land policy consultant to the Joint FAO-World Bank Mission to Peru.

DAVID A. CLARKE, JR., has returned to the University of Cailfornia after spending the past year on a dairy pricing study being conducted by the Market Organization and Costs Branch, Marketing Research Division, AMS. He will continue to serve as consultant to the Branch for this study.

HUBERT L. COLLINS, State Statistician in charge at Topeka, Kansas, died last February. His successor, JASPER E. PALLESEN, was formerly in charge of the Columbus, Ohio, office.

HUGH L. COOK, has returned to the University of Wisconsin, following a year's leave of absence with the ICA in the Phillippines.

R. L. COPPERSMITH has resigned from the position of Assistant Professor of Agricultural Economics at the University of Illinois and has joined the Illinois Livestock Marketing Association.

JOSEPH M. COWDEN has resigned his position with the Dairy Branch of Farmer Cooperative Service to accept a position as Dairying Market Specialist with the ICA. He will be stationed at New Delhi, India.

JOHN F. CRUM, transferred from the State Statistician's office at Jackson, Mississippi, to the Fruit and Vegetable Statistics Branch, Agricultural Estimates Division, Washington, D.C.

J. B. CUNNINGHAM has been promoted to the rank of Professor at the University of Illinois.

REYNOLD P. DAHL has been promoted to Associate Professor at the University of Minnesota.

DOUGLAS J. DALRYMPLE is working as a marketing specialist on fruit merchandizing studies at Cornell.

RICHARD DAY joined the Washington staff of the Farm Economics Research

Division ARS, in June. He has been taking graduate work toward a Ph.D. degree at Harvard University.

BENNETT A. DOMINICK, Associate Professor of marketing at Cornell, is on sabbatical leave for the period July 1 to December 31. While on leave he is with the Market Organization and Costs Branch, AMS, Washington.

WENDELL EARLE has returned to Cornell after a sabbatical leave spent at the National Agricultural Extension Center for Advanced Study at the University of Wisconsin. At Cornell he assumes responsibility for the new program in food distribution.

K. ROBERT ELLINGER of the Department of Agricultural Economics, Ontario Agricultural College, has resigned to take a position in Paris with the Organization for European Economic Co-operation.

AUSTIN EZZELL has joined the Ohio State University staff as Extension Specialist in food merchandising.

DONALD E. FARRIS, formerly fruit and vegetable marketing specialist at North Carolina State College, joined the Agricultural Economics staff at the University of Arkansas in July.

WILLIAM E. FOLZ has returned to the University of Idaho after spending a sabbatical year with the Market Organization and Costs Branch, AMS, doing research on the procurement practices of major food retailing organizations. ALLEN B. PAUL has joined the Market Organization and Costs Branch further to develop his work.

CHARLES E. FRENCH has been appointed Assistant Head of the Department of Agricultural Economics at Purdue University. He replaces LYNN S. ROBERTSON, who is now in Brazil.

FRASIER T. GALLOWAY, transferred from the Fruit and Vegetable Statistics Branch, to the Livestock and Poultry Statistics Branch, Agricultural Estimates Division, Washington, D.C.

RAFAEL GARCIA-ORTEGA, University of Puerto Rico, is spending six months with the Market Organization and Costs Branch, Marketing Research Division, AMS, studying techniques used in marketing research.

ERNEST D. GOOCH has returned to his position as Assistant Economist in the Kentucky Agricultural Experiment Station after having spent a year in graduate work at the University of Illinois.

ELCO GREENSHIEDS, Farm Economics Research Division, ARS, returned July 1 after a four months' assignment with FAO in East Pakistan, where he carried out an over-all economic appraisal of the Ganges-Kobadak irrigation project.

LEIGH H. HAMMOND has been employed by the Market Organization and Costs Branch, AMS, to study vegetable processing in the Southeast. He will be located at Raleigh, North Carolina.

RUSSELL P. HANDY, formerly in charge of the Charleston, West Virginia, State Statistician's office, is now in charge of the office at Columbus, Ohio.

ARNO J. HANGAS has been employed by the Farm Supplies Branch of Farmer Cooperative Service.

JOHN H. HECKMAN has resigned as Chief of the Membership Relations Branch of Farmer Cooperative Service to accept an assignment with the ICA mission to India.

WARD HENDERSON is the new head of the State Statistician's Office, Sacramento, California. He succeeds NIELS I. NIELSEN who retired in July.

CLIFFORD HILDRETH has resigned from the Department of Agricultural Economics to be Head of the Economics Department of Michigan State University effective September 1, 1958.

R. J. HILDRETH resigned from the position of Associate Professor of Agricultural Economics at Texas A and M College effective September 1, to become coordinator for agricultural research at the Texas Agricultural Experiment Station in West Texas.

RAYMOND W. HOECKER, head of the Wholesaling and Retailing Section, Marketing Research Division, AMS, received a superior service award for "leadership and effectiveness in research to develop efficient wholesaling and retailing operations in food distribution and for achieving a high level of industry acceptance of results."

O. WENDELL HOLMES, JR., has joined the staff of the Farm Economics Research Division, ARS, at Montana State College, where he will do research on adjustment problems on farms with limited resources in western Montana.

W. DAVID HOPPER, Department of Agricultural Economics, Ontario Agricultural College, participated in a six weeks' seminar at Ohio State University sponsored by the Council for Economic and Cultural Activities.

GORHAM HUSSEY has joined the Purdue staff as a specialist in fruit and vegetable marketing. Hussey recently completed requirements for the M.B.A. at the Harvard Business School.

HARVEY M. HUTCHINGS has accepted a full-time position as a cooperative agent of AMS-OSC at Oregon State College. He will do research in the area of interregional competition affecting the pea industry.

KENNETH JAMESON has been appointed as an instructor at Kansas State College to assist in the development of the economic information program.

PAUL R. JOHNSON has accepted a position as Assistant Economist in the Kentucky Agricultural Experiment Station after completing graduate study for the Ph.D. at the University of Chicago.

A. D. JONES, Agricultural Economist, USDA, has been transferred from New Mexico A and M to Texas A and M where he will continue in wool marketing research.

DONALD B. JONES, transferred from the Topeka, Kansas, State Statistician's office to the Dairy Statistics Branch, Agricultural Estimates Division.

ROBERT JONES has been appointed instructor at Kansas State College to assist in the development of the economic information program.

TED L. JONES joined the staff of the Farm Economics Research Division, ARS, at Columbia, Missouri, in June.

C. R. KEATON, Extension Economist at New Mexico A and M College, GUY W. MILLER, Agricultural Economist and Professor of Agricultural Economics at Ohio State University, and HAMEED M. FAROOQUI, lecturer in Agricultural Economics, University of Karachi, are co-authors of a new book entitled *Agricultural Marketing in Pakistan*.

JOHN O. KLING, New Mexico A and M College, Extension Farm Management Specialist, resigned effective October 1 to take a position as Agriculture Economics Adviser with the ICA, Santiago, Chile.

HENRY A. KNOPF has a teaching position in the economics department of Niagara University, Niagara Falls, New York.

JOSEPH KOUDELE of Kansas State College has been promoted to Associate Professor.

N. G. P. KRAUSZ has been promoted to the rank of Professor at the University of Illinois.

ALVIN S. LACKEY has joined the Department of Agricultural Economics, Ontario Agricultural College, as an Assistant Professor and will conduct teaching, research and extension in rural sociology.

STEWART H. LANE has become a full-time member of the Department of Agricultural Economics, Ontario Agricultural College, and will participate in a teaching and research program in business management.

LAUREL D. LOFTSGARD recently joined the staff at North Dakota Agricultural College as Assistant Professor of farm management and production economics.

L. LORINEZ has been appointed FAO Regional Marketing Specialist for Latin America with permanent headquarters in Santiago, Chile.

C. V. LYLE, Farm Economics Research Division, ARS, transferred from Little Rock, Arkansas, to Raleigh, North Carolina, in July.

JOHN F. MAHILL joined the staff of the Farm Economics Research Division, ARS, at State College, New Mexico, in June.

ROBERT G. MARSHALL, Assistant Professor in the Department of Agricultural Economics, Ontario Agricultural College, has been granted leave of absence to undertake further graduate studies at the University of Toronto.

LEE R. MARTIN, formerly Associate Professor at North Carolina State College, joined the Agricultural Economics staff of the University of Arkansas as Professor, September 1.

JOHN G, MCNEELY is on a one year leave of absence from his position as Professor of Agricultural Economics at Texas A and M. College to serve as visiting Professor under the sponsorship of the Ford Foundation, to Gokhale Institute, Poona, India.

JOHN W. MELLOR was recently promoted to Associate Professor of Agricultural Geography at Cornell.

ALAN R. MILLER, formerly in the State Statistician's office at Harrisburg, Pennsylvania, has been placed in charge of the office at Charleston, West Virginia.

JOHN MITCHELL has joined the Ohio State University staff as Extension Specialist in Rural Sociology. He was previously at the University of Rhode Island.

JOE L. MOBLEY, formerly principal of Oneida, Kentucky, has been appointed Extension Specialist in Agricultural Economic Development at the University of Kentucky.

JOE E. MULLIN, transferred from the Fruit and Vegeatable Statistics Branch, Washington, D.C., to the State Statistician's office at Sacramento, California.

ROBERT D. MUNSON has resigned his position with the TVA Agricultural Economics Branch. He has accepted the position of agronomist with the American Potash Institute, St. Paul, Minnesota.

SAAD NAGI received his Ph.D. in August from Ohio State University and will join the research staff with the rank of Assistant Professor.

KENNETH C. NOBE, who is completing his graduate studies at Cornell, will be employed in the Land and Water Utilization Branch, ARS, to work on the Potomac River survey.

TRUMAN R. NODLAND has been promoted to Associate Professor at the University of Minnesota.

ELMER R. NORDBERG transferred from the State Statistician's office, Harrisburg, Pennsylvania, to the Trenton, New Jersey, office.

MERTON OTTO of Kansas State College has assumed the responsibility as coordinator for the Kansas State ICA-India program.

T. R. OWENS, agricultural economist with the AMS in Washington, D. C., is being transferred from New York to Oregon State College where he will work with S. K. Christensen on the market structure problems of the Oregon dairy industry.

ROSS L. PACKARD transferred from the State Statistician's office, Columbus, Ohio, to the Special Statistics Branch, Agricultural Estimates Division, Washington, D.C.

ROBERT D. PARR transferred from the State Statistician's office at Portland, Oregon, to the office at Sacramento, California.

DAVID H. PENNY has taken a position with the University of Sumatra at Medan, Indonesia. He is sponsored by the Council on Economic and Cultural Affairs.

BOBBY H. PENTECOST has been employed by the Farm Supplies Branch of Farmer Cooperative Service.

BRIAN B. PERKINS has joined the Department of Agricultural Economics, Ontario Agricultural College, as an assistant and will undertake research in marketing.

VERNON PHERSON has joined the staff at Purdue as Assistant Professor in livestock marketing and research, after recently completing requirements for the Ph.D. at Purdue.

M. GLADE PINCOCK is now working as a research associate on studies of costs of production of minor agricultural enterprises at Cornell.

ROY POTAS, formerly in the Dairy Statistics Branch, Agricultural Estimates Division, AMS, Washington, is now head of the Sioux Falls, South Dakota, State Statistician's office. He succeeded CARY D. PALMER.

E. L. POTTER, Emeritus Professor and Head of Agricultural Economics at Oregon State College, has accepted a temporary assignment as Short Course Director for a group of foreign students who are enrolling at Oregon State College in September for a three-month intensive training program in agricultural marketing, sponsored by ICA.

DEWEY L. PRITCHARD, Mississippi State College, and HAZEN F. GALE, University of California, have joined the staff of the Market Organization and Costs Branch, Marketing Research Division, AMS.

F. J. REISS, University of Illinois, will be on sabbatical leave for six months beginning March 1, 1959, to study farm consolidation efforts and the impact of the Common Market in West Germany and Holland, and to observe the English land tenure system.

LYNN S. ROBERTSON is coordinator in Brazil for the new Cooperative Training program between Purdue and Brazil's 12 agricultural colleges and eight veterinary schools.

KENNETH L. ROBINSON was recently promoted to Professor of Agricultural Economics at Cornell.

ROBERT W. RUDD has been promoted to Economist in Agricultural Economics in the Kentucky Agricultural Experiment Station. He also is Professor of Agricultural Economics at the University of Kentucky.

IRWIN R. RUST has been appointed Chief of the Membership Relations Branch, Farmer Cooperative Service.

VERNON RUTTAN is on leave from Purdue University this academic year to conduct special research in water resource allocation problems at the Giannini Foundation, University of California, Berkeley.

JOHN SCHNITTKER, Kansas State College, has been promoted to Associate Professor.

LEONARD SCHRUBEN, Kansas State College, has assumed half-time responsibilities with the Extension Service to Coordinate the extension economic information program.

WILLIAM E. SCHRUMPF, Associate Agricultural Economist in the Maine Agricultural Experiment Station, retired June 30. He became an Emeritus of the University.

ROBERT SCHWART received his Ph.D. degree at Ohio State University in August, and will continue on the staff as extension specialist in farm management.

CLAUD L. SCROGGS, Associate Agricultural Economist, has resigned from the staff at the University of Tennessee to accept a position with Southern States Cooperative, Richmond, Virginia.

D. MILTON SHUFFETT has been promoted to Associate Professor of Agricultural Economics at the University of Kentucky.

F. M. SIMS has joined the staff of the University of Illinois as supervisor of the extension test-demonstration program in Illinois.

DONALD G. SMITH joined the staff of the University of Illinois in September as Manager of the University trust farms. He has been manager of the Farm Service Department of the First Trust and Savings Bank of Kankakee.

ROBERT S. SMITH was recently promoted to Professor of Farm Management at Cornell.

B. RALPH STAUBER, Chief of the Price Statistics Branch, Agricultural Estimates Division, AMS, was one of 50 winners of a $500 award for his essay, "What is the Most Important Economic Problem to be Faced by the United States in the Next 20 Years?" The competition was sponsored by the Committee for Economic Development. He has also received a superior service award "for excellence in directing the agricultural price estimating program and aiding in its effectual application of broad policies and problems relating to the agricultural economy."

CHRISTIAN A. STOKSTAD from the Seattle, Washington, office of the State Statistician, was one of the two USDA employees chosen to participate in the 1958 Management Intern Program of the U. S. Civil Service Commission. The program runs for five months.

GLENN W. SUTER transferred out of the Special Statistics Branch, Agricultural Estimates Division to the Statistical Standard Division.

E. R. SWANSON has been promoted to the rank of Professor at the University of Illinois.

DANIEL A. SWOPE joined the Department of Agricultural Economics, University of Maryland, as an Assistant Professor. He completed the Ph.D. degree in August at Pennsylvania State University.

JOHN R. TEDFORD has accepted a position as Agricultural Economist with the Agricultural Economics Branch, Division of Agricultural Relations, TVA.

D. M. THORPE, who has been Acting Head of the Department of Agricultural Economics, University of Tennessee, for the past two years, has been appointed Assistant Director of the Tennessee Agricultural Extension Service.

F. RIDGLEY TODD, JR., has been appointed Extension Specialist in vegetable marketing at the University of Massachusetts.

RAPHAEL TRIFON joined the staff of the Department of Agricultural Economic and Farm Management of the University of Manitoba as a post-doctorate fellow. He is graduate of the Hebrew University, Jerusalem, and has a Ph.D. in Agricultural Economics from the London School of Economics.

LAWRENCE VAN MEIR, formerly with FAO in Mexico, has been appointed Assistant Professor at Kansas State College. He will work in the area of market prices.

HERBERT M. WALTERS transferred from Head, Fluid Milk and Cream Section, to Head, Milk Products and Utilization Section, Dairy Statistics Branch, Agricultural Estimates Division.

PETER DALE WEBER transferred from the Chicago Dairy Office of the Agricultural Estimates Division to the Dairy Statistics Branch, Agricultural Estimates Division, Washington, D.C.

THOMAS J. WHATLEY has been appointed Acting Head of the Department of Agricultural Economics and Rural Sociology, University of Tennessee. He will also continue as Program Director for the Ames Plantation.

ROBERT J. WILLIAMS recently took up his duties as an extension economist at Cornell.

MARTIN D. WOODIN, Louisiana State University, was elected chairman of the recently organized Tri-state Committee on Farmer Cooperative Research and Education in New Orleans. EARL BEALL, assistant general manager of Mississippi Federated Cooperatives, is vice-chairman, and R. M. GRIGSBY, extension marketing specialist at Louisiana State University, is secretary. The committee is composed of representatives of research and educational agencies, credit institutions, and cooperatives from Alabama, Mississippi, and Louisiana. Its purpose is to encourage research and education in agricultural cooperation.

RICHARD B. ZOLLER is now Agricultural Economist in the Research Department of F. H. Peavey Company, Minneapolis. He was formerly an instructor at the University of Minnesota where he received the Ph.D. degree in June.

J. S. CANNER AND COMPANY, INC., Boston, Massachusetts, has Microcard reprints of the *Journal of Farm Economics*, Volumes 1 to 5, available at $2.50 per volume.

THE AGRICULTURAL RESEARCH POLICY COMMITTEE of the U. S. Department of Agricultural and chairmen of the Department's 25 research and marketing advisory committees recently reviewed the USDA advisory-committee system, endorsed its continued operation, and reaffirmed the importance of research to agriculture. The meeting agreed that the country's 4 million farmers, "although making up, in the aggregate, the Nation's largest industry, are too small as individuals to do their own research." Members of the two groups concluded that "public support of agricultural research is therefore essential. Research is a practical necessity in finding the answers to present-day farm problems and in charting a course for future program action in the best interest of the Nation," and agreed that "basic research will set the pace, to a large degree, for more productive applied research in the future."

MEMBERS OF THE U. S. exchange delegation of agricultural economist to the U.S.S.R., who spent the month of July in that country, included SHERMAN JOHNSON, Scientific and Professional Advisor, Agricultural Research Service; CARL P. HEISIG, Director, Farm Economics Research Division, ARS; HAROLD BREIMYER, Agricultural Economics Division, AMS; WALLACE KIRKBRIDGE, Agricultural Estimates Division, AMS; and LAZAR VOLIN, Foreign Agricultural Service. In Moscow, conferences were held with the Soviet Minister of Agriculture and with officials of the Institute of Agricultural Economics, the Institute of Economics of the Academy of Science, and the State Planning Commission. The group travelled about 12,000 miles inside the Soviet Union, visiting state and collective farms, research stations, and other agricultural enterprises in 10 major farming areas.

PROGRAM OF AMERICAN FARM ECONOMIC ASSOCIATION AT JOINT SOCIAL SCIENCE ASSOCIATION MEETINGS IN CHICAGO, ILLINOIS, DECEMBER 27-29, 1958

December 27, Morning Session: *Joint with Econometric Society*

Chairman: Karl Fox, Iowa State College
Linear Programming Models for the Determination of Palatable Human Diets–
Victor E. Smith, Michigan State University
An Econometric Model of the Egg Economy–
Martin J. Gerra, U. S. Department of Agriculture
Discussants: Charles Zwick, Rand Corporation; One to be announced.

December 28, Morning Session: *Joint with Econometric Society*

Chairman: To be announced.
The Demand for Inputs and a Derived Supply Curve–
Zvi Griliches, University of Chicago
The Farm Demand for Tractors, Machinery, and Trucks–
William A. Cromarty, Michigan State University
Fertilizer Demand Functions for the United States and Selected Regions–
Martin H. Yeh and Earl O. Heady, Iowa State College

December 28, Afternoon Session: *Joint with American Marketing Association*

Chairman: George Mehren, University of California
The Promotion of Farm Products, a Theoretical Analysis–
Sidney Hoos, University of California
Research on the Effectiveness of Farm Products Promotions–
Frederick V. Waugh, U.S. Department of Agriculture
Discussants: Shelby Robert, American Dairy Association; Seymour Banks, Leo Burnett Company, Chicago; E. L. Baum, Tennessee Valley Authority; One to be announced.

December 29, Morning Session: *Joint with American Economic Association*

Topic: The Significance of Industrial Organization and Market Structure to Development and Marketing Problems

Chairman: Robert L. Clodius, University of Wisconsin
Changing Structure of the American Economy: Its Implications for Performance of Industrial Markets–
Jesse W. Markham, Princeton University
Changing Structure of the American Economy: Its Implication for The Performance of Agricultural Markets–
Willard W. Cochrane, University of Minnesota
Some Market Structure Considerations in Economic Development–
Willard F. Mueller, University of Wisconsin
Discussants: Walter Adams, Michigan State University; Norman R. Collins, University of California; Harry C. Trelogan, Agricultural Marketing Service, USDA

December 29, AFEA Evening Dinner Session

Topic: The International Conference of Agricultural Economists
Panel Discussion:
Moderator: H. C. M. Case, University of Illinois
Panelists: Joseph Ackerman, Farm Foundation; Three to be announced.

AGRICULTURAL HISTORY

Published by the Agricultural History Society

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Volume 32 *July 1958* *Number 3*

A French Aristocrat Looks at American Farming .....DAVID J. BRANDENBURG
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THE JOURNAL OF POLITICAL ECONOMY

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RURAL SOCIOLOGY

Vol. 23, No. 3

Official Journal of the Rural Sociological Society

Published at

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The journal subscription rate to nonmembers, libraries and institutions is $7.00 per year in the United States and Canada, $7.50 per year to all other countries, postage paid. Membership in the Rural Sociological Society which includes the journal is $7.00 per year in the United States and Canada, $7.50 a year in all other countries.

JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

Volume 53 *September, 1958* *Number 283*

ARTICLES

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Demand for Farm Products at Retail and the Farm Level. Some Empirical Measurements and Related Problems — REX F. DALY

Investment Estimates of Underdeveloped Countries: An Appraisal — WILLIAM I. ABRAHAM

Manufacturers' Inventory Cycles and Monetary Policy — DORIS M. EISEMANN

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A Test of Variances — M. V. RAMACHANDRAN

Book Reviews

Notes About Authors

Publications Received

American Statistical Association—1757 K Street, N. W., Washington 6, D.C.

AMERICAN ECONOMIC REVIEW

Volume XLVIII *September 1958* *Number 4*

Articles

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Communications

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Editorial communications including manuscripts submitted for publication or inquiries concerning the *Journal* should be addressed to Robert L. Clodius, Department of Agricultural Economics, University of Wisconsin, Madison 6, Wisconsin. Communications concerning books for review and books, bulletins and other publications submitted for announcement in the *Journal*, should be addressed to George G. Judge, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

Applications for membership, changes in address, or inquiries regarding the general affairs of the Association should be addressed to Lowell S. Hardin, Agricultural Hall Annex, Purdue University, Lafayette, Indiana.

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